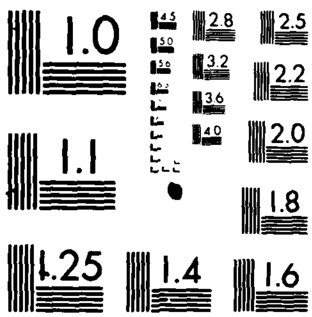
AD-A116 075   SCIENTIFIC TECHNOLOGY ASSOCIATES INC PRINCETON NJ   F/G 9/2
OPTICAL DETECTION SYSTEM MODEL.(U)
APR 82   E S FISHBURNE, J V KUHLMAN   F30602-80-C-0120
UNCLASSIFIED   RADC-TR-82-60   NL

END
DATE
FILMED
7-82
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD A116075

(12)

RADC-TR-82-60
Final Technical Report
April 1982

OPTICAL DETECTION SYSTEM MODEL

Scientific Technology Associates, Inc.

E. Stokes Fishburne
Frank J. Brickle
Jeanne V. Kuhlman
Margaret P. Cundiff

ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

This report has been reviewed by the RADC Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be releasable to the general public, including foreign nations.

RADC-TR-82-60 has been reviewed and is approved for publication.

APPROVED: Melvin Manor

MELVIN MANOR
Project Engineer

APPROVED: A. J. Driscoll

ALAN J. DRISCOLL, Colonel, USAF
Chief, Intelligence & Reconnaissance Division

FOR THE COMMANDER: John P. Huss

JOHN P. HUSS
Acting Chief, Plans Office

If your address has changed or if you wish to be removed from the RADC mailing list, or if the addressee is no longer employed by your organization, please notify RADC (IRAA) Griffiss AFB NY 13441. This will assist us in maintaining a current mailing list.

Do not return copies of this report unless contractual obligations or notices on a specific document requires that it be returned.

MISSION
of
Rome Air Development Center

RADC plans and executes research, development, test and selected acquisition programs in support of Command, Control Communications and Intelligence (C^3I) activities. Technical and engineering support within areas of technical competence is provided to ESD Program Offices (POs) and other ESD elements. The principal technical mission areas are communications, electromagnetic guidance and control, surveillance of ground and aerospace objects, intelligence data collection and handling, information system technology, ionospheric propagation, solid state sciences, microwave physics and electronic reliability, maintainability and compatibility.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER RADC-TR-82-60	2. GOVT ACCESSION NO. AD-A116 075	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) OPTICAL DETECTION SYSTEM MODEL		5. TYPE OF REPORT & PERIOD COVERED Final Technical Report
		6. PERFORMING ORG. REPORT NUMBER N/A
7. AUTHOR(s) E. Stokes Fishburne, Margaret P. Cundiff, Jeanne V. Kuhlman, Frank J. Brickle		8. CONTRACT OR GRANT NUMBER(s) F30602-80-C-0120
9. PERFORMING ORGANIZATION NAME AND ADDRESS Scientific Technology Associates, Inc. 1101 N. State Road, Building N Princeton NJ 08540		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 64750F 2053A003
11. CONTROLLING OFFICE NAME AND ADDRESS Rome Air Development Center (IRAA) Griffiss AFB NY 13441		12. REPORT DATE April 1982
		13. NUMBER OF PAGES 90
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Same		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Same

18. SUPPLEMENTARY NOTES

RADC Project Engineer: Melvin Manor (IRAA)

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electro-Optical
Detection System
Sensors
Computer Code
Response Functions

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An Optical Detection System (ODS) computer code has been developed for the simulation of an electro-optical sensor. The primary emphasis has been devoted to modeling the temporal response of the system to an arbitrary time varying input signal. Input signals comprised of several wavelengths also can be treated. The ODS code consists of the following modules: SOURCE MODULE permits the selection of a number of standard input signals (or the user's signal) as well as white noise and 1/f noise, OPTICS (over)

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

MODULE includes a wide range of optical materials and transmissivities as a function of wavelength as well as an etalon option. MODULATOR MODULE which enables the user to select a chopper, circular variable filter, a Fourier transform spectroscopy, DETECTOR MODULE provides a range of detector materials including wavelength response and temporal response characteristic, PREAMP/AMPLIFIER MODULES enable the user to select a low pass filter, high pass filter, band pass filter, band rejection filter and a set of amplifiers the characteristics of which are expressed in poles and zeroes. The user also may supply his own amplifier characteristics either in terms of poles and zeroes or in the form of a gain curve. In addition to the standard sensor type modules the ODS code includes many utility modules such as PLOT, FFT, EDIT and CONVOLUTION. The ODS code is extensively user oriented for ease of operation. The code is designed to be used either in an interaction mode with a CRT or bulk mode employing data files.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

The "Optical Detection System Model" (ODS Computer Code) was developed under Contract F30602-80-C-0120 to Rome Air Development Center (RADC). The overall effort was intended to provide analysts with a computerized algorithm to simulate and evaluate the temporal and wavelength response of electro-optical detection systems.

1.1 Overview of Optical Detection System Model Computer Code

Ideally, a computerized electro-optical detection system should include every important phenomenon encountered by the radiation as it proceeds from the source to the sensor, is processed by the sensor, recorded, and displayed on a graphics terminal. A sample scenario is shown in Figure 1.1 for the detection of a pulse from a laser as it is scattered and attenuated by the atmosphere.

The development of a computer code for the simulation of electro-optical detection systems must, at a minimum, meet three basic requirements:

- o The computer code must be user oriented
- o The computer code must be of modular construction, and
- o The computer code must be computationally efficient.

The ODS computer code was designed around these basic requirements.

1.1.1 User Oriented

The key to any successful computer code is that it be easy to use both by the individual generally unfamiliar with the code and those who routinely use the code. This requires that the input data be easily understood and concise. This aspect of the ODS code development was given the primary priority. The user is presented with a series of "PROMPTS" on the screen of the CRT terminal. Simply by answering a series of questions the user is led through such items as the optical filter selection, detector material selection, amplifier type, frequency response, etc. In addition, a number of "standard" input signals can be generated by the ODS code providing both the experienced and inexperienced user with the selection of an arbitrary source signal (to be

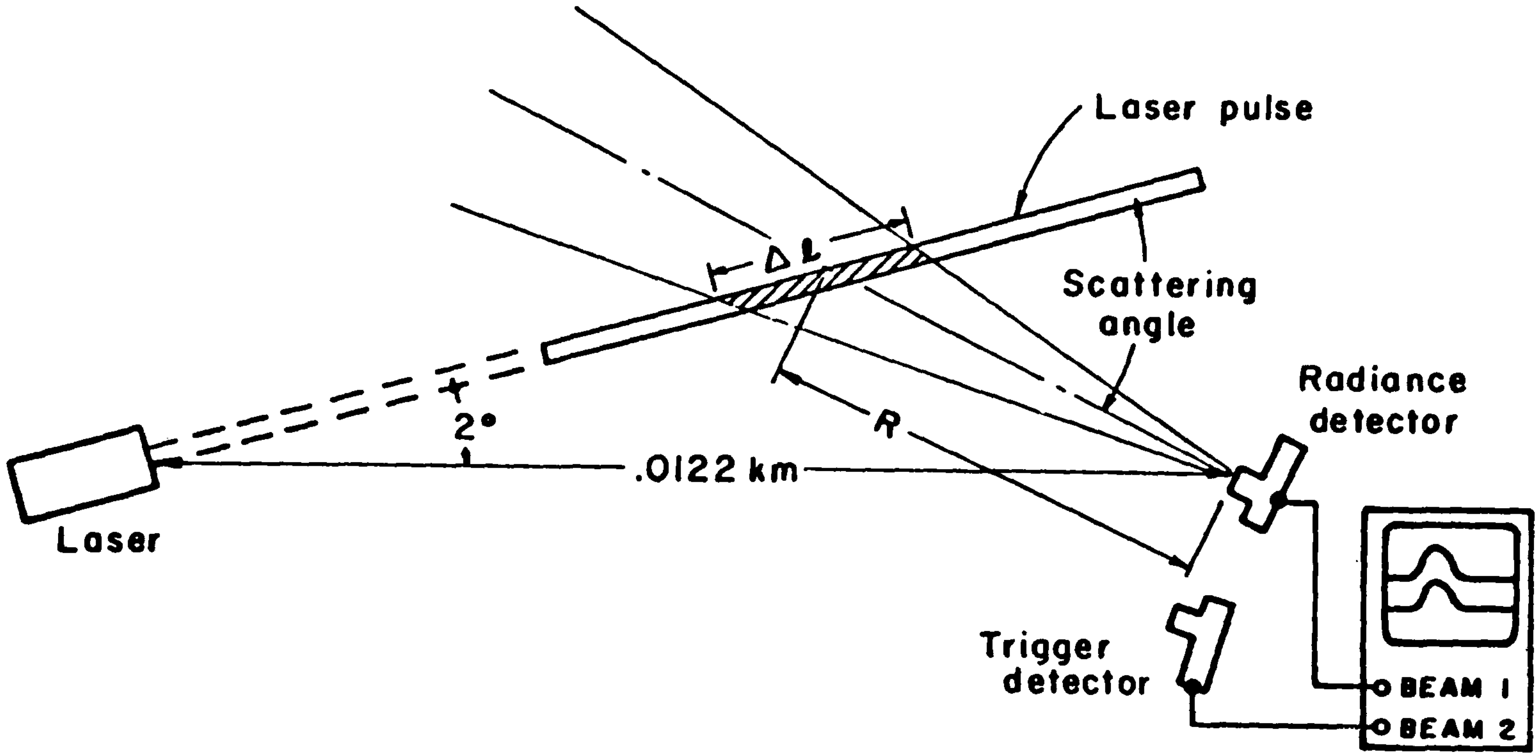


Figure 1.1 Geometry of Laser Scattering Measurement Experiment

input by the user) or the use of one of the supplied source signals. The supplied signals are such that the intensity and time may be scaled by the user to provide a wide range of possible signal temporal/intensity histories.

The inexperienced user (or even the experienced user) can ask for assistance from the computer at each entry point into many of the system modules. A message appears on the CRT screen which has information pertinent to the input being considered. The experienced user can either employ the "PROMPT" approach or can employ input data files already set up through previous use of the ODS code. Of course, the experienced user may have the option of using any input file at his disposal for running the code.

1.1.2 Modular Construction

The computer code is constructed in modules which represent different facets of the system. In this way as more options are developed these can be inserted into the code with a minimum of difficulty. An excellent example of this feature is the selection of the detector material. A wide range of detector materials has been incorporated as part of the resident data file in the ODS code. However, as new detector materials are desired these new materials can be incorporated into the code with relative ease.

The modules currently employed include:

- SOURCE MODULE — Permits the user to select any one of a number of stored source signals such as sine waves, square waves, step input, etc., or it permits the user to input his own signal.
- ATMOSPHERIC MODULE — Permits the user to specify atmospheric conditions for modifying the signal. This routine currently copies the input signal to the output. It is only provided as a means of program extension at a later date.
- OPTICS MODULE — Permits the user to specify the type of optical material used in the collector to determine the attenuation of the signal at each wavelength. This module also contains spectral filter and etalon characteristics.

o	MODULATOR MODULE	Permits the user to choose one of three modulating techniques: chopper, circular variable filter, or Fourier Transform Spectroscopy.
o	DETECTOR MODULE	Permits the user a choice of visible and infrared detector materials which includes spectral response as well as frequency response.
o	AMPLIFIER/ PREAMPLIFIER MODULES	Permits the user a selection of amplifier response functions including low pass, high pass and band pass amplifiers.

In addition to the modules indicated above, each of which can be run as a separate computer program, a set of UTILITY programs are available which enables the user to EDIT files and PLOT data. All of the basic modules will be discussed in the following sections. The UTILITY programs are discussed in detail in the Program Users Manual (Ref. 1) and the Program Maintenance Manual (Ref. 2).

1.2 Application

It is anticipated that the primary application of the computer code is the simulation of the temporal response of sensor to an arbitrary, time dependent input signal. For this reason special consideration has been given to the frequent use of graphs of the signal before it enters a particular module and as it exits. In this way the influence of the particular module on the temporal characteristics of the signal (i.e., distribution) can be readily observed. In addition, the construction of the ODS code greatly simplifies the selection of preamp/amplifier design, for instance, since the user may examine the output, change the design, and rerun only that part of the code in a matter of minutes.

It is further anticipated that the code may be used to simulate electro-optical data in the presence of noise to examine data processing techniques. Therefore, care was taken to insure that the frequency/phase information content of the signal was unchanged. For this reason, the impulse invariant technique was used for treating the preamp/amplifier impulse response functions. The limitations of this technique are discussed in Section 4.5.

The ODS code provides a unique method for introducing "new" engineers to the temporal response characteristics of electro-optical sensors. In addition, with several modifications, the ODS code could be employed to assist in the overall design of electro-optical sensors. These modifications are discussed in Section 5.

2. SYSTEM SUMMARY

This section provides a brief summary of the overall ODS computer code with respect to systems requirements, data bases, and input/output requirements. Additional information may be found in the Program Maintenance Manual and Program Users Manual.

2.1 System Application

The Optical Detection System (ODS) Model computer code is designed to be used interactively by the operator in the evaluation of overall performance of electro-optical sensors. The ODS code is designed such that the operator can analyze any portion of the electro-optical sensor such as the filters, amplifier characteristics, detector characteristics, and sensor modulation characteristics. The operator may either analyze each component independently, as groups of components, or as the entire electro-optical sensor. The operator may employ stored signals for testing each component or may provide his own particular signal.

2.2 System Organization

The ODS computer code consists of 20 different tasks. Each of the modules mentioned earlier can be run separately, as well as programs for convolution, editing, display, plotting, and summing output for multiple wavelengths. The entire control of the overall operation of the ODS code is maintained through an indirect command file - ODSRUN. The execution of the command @ODSRUN initiates a series of commands which enables the operator to establish any combination of running modules including the generation of plot files. The first pass through the command file enables the user to provide the necessary input information required by each of the modules. After the INPUT phase the operator may edit any of the data files through the EDIT command in the ODSRUN command file. When the user is satisfied with the input he can execute the overall computation process through the RUN command.

The organization of the ODS code around a master command file provides great flexibility in adding new modules and in placing the code on other computers. The primary changes required to place the code on the UNIVAC, for instance, are made in the ODSRUN.CMD command file. In this file, the appropriate statements pertinent to the UNIVAC can be inserted and the same overall structure of the code employed. The different programs accessed by the ODSRUN command file are indicated in Table 1. The ODS code also contains three data bases, one each for the OPTICS module, DETECTOR module, and AMPLIFIER/PREAMPLIFIER modules. These data bases can be easily amended to contain additional data.

TABLE 1

Running Tasks Accessible to ODSRUN Command File

PROGRAM	FUNCTION
ODSWV	Runs SOURCE module
WVINP	Provides input to SOURCE
ODSATM	Runs ATMOSPHERE module
ATMINP	Provides input to ATMOSPHERE
ODSLNS	Runs OPTICS module
LNSINP	Provides input to OPTICS
ODSMOD	Runs MODULATOR module
MODINP	Provides input to MODULATOR
ODSDET	Runs DETECTOR module
DETINP	Provides input to DETECTOR
ODSHVP	Runs PREAMPLIFIER module
HVPINP	Provides input to PREAMPLIFIER
ODSHVY	Runs AMPLIFIER module
HVYINP	Provides input to AMPLIFIER
ODSEDR	Runs EDIT routine
ODSDSP	Runs DISPLAY routine
ODSTOT	Runs routine which sums results for multiwavelength
CNVL	Runs CONVOLUTION routine
ODSGRF	Runs PLOT routine which sets up plot file
ODSXQT	Runs main module for selecting sequence

2.3 Data Base

The ODS computer code employs three data bases. The OPTICS module requires a data base which contains the basic transmission characteristics of the various optical materials and filters. A sample portion of the data set is given in Table 2. The first line in each data set contains the code name of the material, the thickness (mm), the lower wavelength (microns), upper wavelength (microns), and the number of wavelength-transmissivity data pairs. The next lines are the wavelength-transmissivity data pairs. In all cases the wavelength

TABLE 2

SAMPLE CONTENTS OF OPTICAL MATERIAL FILE ODSOPT.INP

SRF2	3.000	0.120	13.000	9.000
	0.120	0.100		
	0.130	0.600		
	0.200	0.850		
	0.300	0.910		
	0.630	0.940		
	0.850	0.950		
	10.000	0.900		
	12.000	0.500		
	13.000	0.030		
VYC7905	2.000	1.000	4.700	15.000
	1.000	0.925		
	2.000	0.925		
	2.600	0.925		
	2.800	0.930		
	3.000	0.920		
	3.200	0.850		
	3.400	0.550		
	3.600	0.100		
	3.800	0.230		
	3.950	0.100		
	4.150	0.200		
	4.300	0.090		
	4.400	0.100		
	4.500	0.050		
	4.700	0.000		
INFRASIL	10.000	1.000	4.300	12.000
	1.000	0.920		
	2.000	0.920		
	2.600	0.920		
	2.700	0.810		
	2.800	0.850		
	3.000	0.840		
	3.100	0.830		
	3.300	0.810		
	3.600	0.630		
	3.900	0.200		
	4.000	0.170		
	4.300	0.000		
SAFPHIRE	1.000	0.200	6.300	8.000
	0.200	0.640		
	0.230	0.770		
	0.330	0.820		
	0.700	0.850		
	3.300	0.850		
	4.000	0.870		
	6.000	0.700		
	6.300	0.100		

is in microns.

The DETECTOR module requires a data base which contains the properties of the various detector materials currently available. A sample of the type of data may be seen in Table 3. The first line of each data set in this file contains the detector temperature (°K), time constant (seconds), and the number of wavelength-D* data pairs. The next lines are the wavelength (in microns) - D* data pairs. D* is the detectivity of the detector.

The AMPLIFIER and PRE-AMPLIFIER modules both access a data file which contains the information necessary to generate a response function for an amp/preamp using the Heaviside routines as indicated in Table 4. The first line of the file contains the code name of the amplifier/preamp, and the number of poles, number of zeroes, multiplicative constant in the quadratic term, prefactor, recommended maximum time duration of the response function and the recommended minimum time step. The time parameters are in seconds. The next lines are the poles and then the zeroes of the amplifier/preamp.

2.4 General Description of Inputs, Processing, Outputs

The inputs required for the ODS code are supplied either by the user in an interactive manner or through the use of data stored in table form. Although the information required by each module must be initially input by the user, the stored input file may be used for additional computer runs. In the following paragraphs we will discuss in detail the input required by each module.

2.4.1 SOURCE MODULE

To operate the ODS code the user must specify the following information whether through prompts or by a previously prepared input file

SIGNAM ----- Name of source signal (see below)

TSTEP ----- TIME STEP (time, in seconds, at which signal is sampled). This is not arbitrary and must be coordinated with the requirements set by the AMPLIFIER/PREAMPLIFIER MODULE

TMAX ----- Duration of input signal (seconds)

WAVEL ----- Wavelength of radiation (microns)

TABLE 3

SAMPLE CONTENTS OF DETECTOR FILE ODSDET.INP

PBS	7.700E+01	5.000E-03	16.000
	5.000E-01	4.000E+10	
	1.000E+00	6.100E+10	
	1.500E+00	8.800E+10	
	1.750E+00	1.020E+11	
	2.000E+00	1.200E+11	
	2.250E+00	1.300E+11	
	2.500E+00	1.600E+11	
	2.750E+00	1.800E+11	
	3.000E+00	2.000E+11	
	3.250E+00	2.200E+11	
	3.500E+00	1.900E+11	
	3.750E+00	1.600E+11	
	4.000E+00	9.800E+10	
	4.250E+00	3.600E+10	
	4.500E+00	1.200E+10	
	4.750E+00	4.000E+09	
PBS	1.930E+02	3.000E-03	13.000
	5.000E-01	1.600E+11	
	7.500E-01	2.000E+11	
	1.000E+00	2.600E+11	
	1.500E+00	3.700E+11	
	2.000E+00	5.200E+11	
	2.250E+00	6.000E+11	
	2.500E+00	6.700E+11	
	2.750E+00	7.000E+11	
	3.000E+00	5.900E+11	
	3.250E+00	3.700E+11	
	3.500E+00	1.000E+11	
	3.750E+00	2.000E+10	
	4.000E+00	2.800E+09	
PBS	2.980E+02	3.500E-04	14.000
	5.000E-01	9.000E+10	
	7.500E-01	1.050E+11	
	1.000E+00	1.200E+11	
	1.250E+00	1.400E+11	
	1.500E+00	1.800E+11	
	1.750E+00	2.000E+11	
	2.000E+00	2.200E+11	
	2.170E+00	2.100E+11	
	2.210E+00	2.000E+11	
	2.250E+00	1.800E+11	
	2.380E+00	1.300E+11	
	2.500E+00	8.000E+10	
	2.750E+00	1.080E+10	
	3.000E+00	7.000E+09	

TABLE 4

SAMPLE CONTENTS OF AMPLIFIER/PRE-AMPLIFIER FILE ODSAMP.INP

```
W  6.000E+00 4.000E+00 7.230E-01 8.960E+10 5.000E-03 1.250E-04
         7.854E+03
         4.712E+01
         3.098E+03
         2.513E+03
         2.513E+03
         3.378E+03
         0.000E-01
         0.000E-01
         0.000E-01
         0.000E-01
H  6.000E+00 4.000E+00 5.400E-01 2.340E+07 2.000E-01 5.000E-03
         7.854E+03
         2.500E-01
         1.092E+02
         6.553E+01
         4.097E+01
         5.460E+01
         0.000E-01
         0.000E-01
         0.000E-01
         0.000E-01
F  6.000E+00 4.000E+00 7.230E-01 2.680E+10 1.000E-02 2.500E-04
         7.854E+03
         4.712E+01
         1.688E+03
         8.143E+02
         8.143E+02
         1.848E+03
         0.000E-01
         0.000E-01
         0.000E-01
         0.000E-01
```

None of this input data has a default value. All are required. Once the user has selected the type of source signal to be employed for the computations, he must then supply the necessary characteristics of the signal. The user will be asked to provide the additional information by specifying the code word for a particular signal. The available source signals include a sine wave, square wave, step-up function, step-down function, triangle wave, ripple on a square wave pulse, white noise, and 1/f noise. Samples of these signals are given in Figure 2.1. In addition to the stored signals the user also may use his own signal as input.

2.4.2 OPTICS MODULE

The OPTICS module contains the basic spectral filter data for wavelength region isolation. OPTICS MODULE requires only the selection of the optical filter material and then certain information necessary for that filter. All filter transmittances are stored in a file in the computer for a particular filter thickness. If a different thickness is input, the program will perform the necessary computation to increase or decrease the transmittance of the desired filter. An etalon type filter may be used also. The necessary information is given in Table 5. Sample transmission curves are shown in Figure 2.2.

In addition to the basic optical/filter materials presented in Table 5, the user may decide to employ an etalon for his basic filter. The mathematical formulation for the etalon is provided in Section 3.1.2. The input requirements for using the etalon option are given below.

ODS code word = ETALON

CENTERLINE WAVELENGTH -	Wavelength of the centerline of the etalon (if 0.0, assumed = to wavelength input in beginning of run).
TRANSMISSIVITY ------	Transmissivity at the line center
INDEX OF REFRACTION ----	Effective index of refraction of etalon (Sample values 2. - 5.)
HALFWIDTH ------	Halfwidth of the etalon function at the halfpower point
ANGLE ------	Angle of incident radiation (0° = normal incidence and 10° maximum)

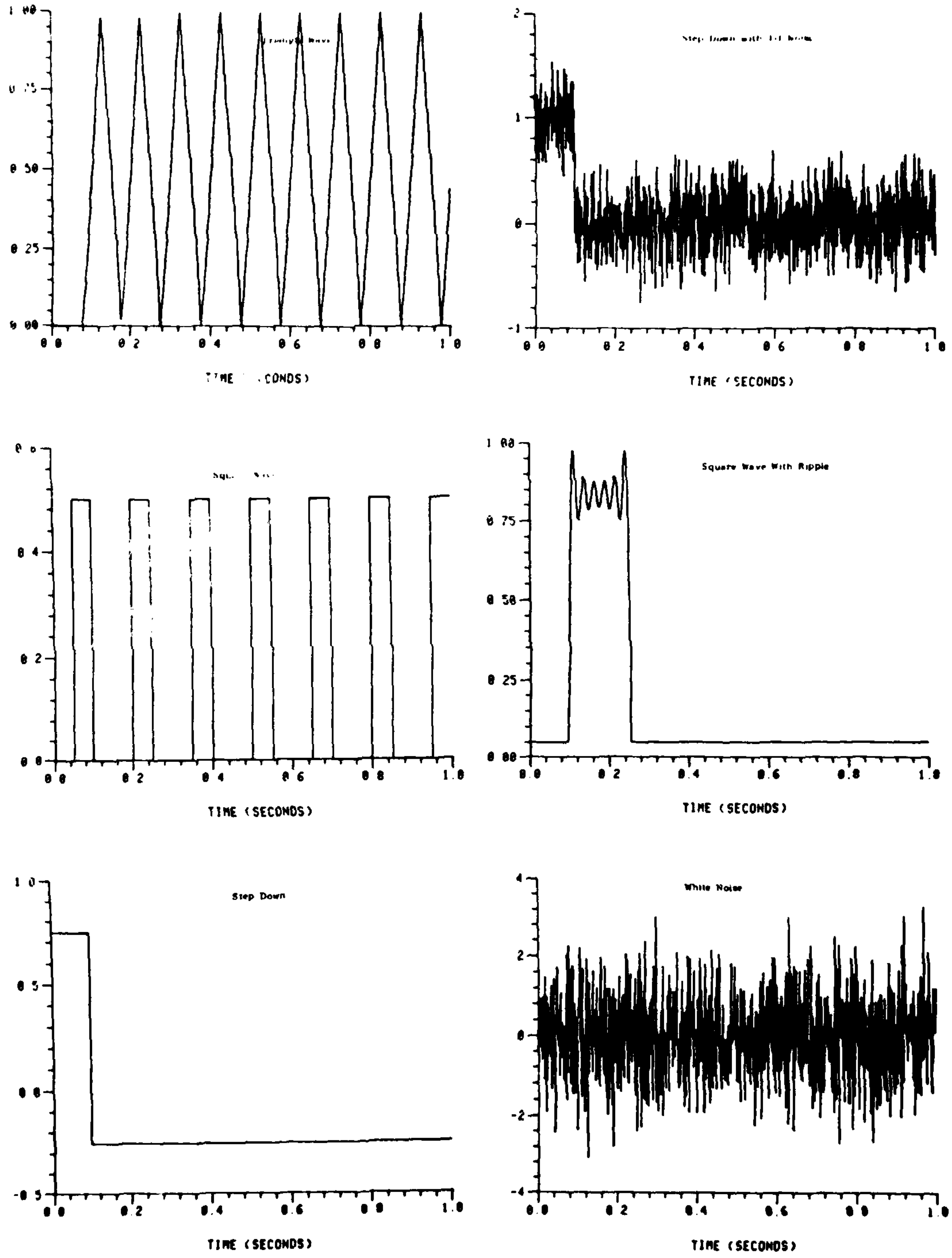


Figure 2.1 Samples of the Input Signals which can be generated by the SOURCE MODULE.

TABLE 5

Characteristics of Optical Material

Material	Thickness (mm)	Wavelength Region (microns) Lower	Upper
Corning 1865 J	2.0	1.0	5.25
Vycor	2.0	1.0	4.8
Fused Silica	2.0	1.0	5.0
Magnesium Fluoride	1.0	0.3	8.0
Strontium Fluoride	3.0	0.12	13.0
Vycor 7905	2.0	1.0	4.7
Infrasil Suprasil	10.0	1.0	4.3
Sapphire (Alumina)	1.0	0.2	6.3
Magnesium Oxide	2.0	0.23	9.8
Titanium Dioxide	6.0	0.41	5.5
Cadium Selenide	6.0	0.70	23.0
Cadium Sulfide	2.0	0.5	17.0
Cadium Telluride	2.0	0.82	28.0
Amorphous Selenium	1.69	1.0	20.0
Zinc Selenide	2.0	0.49	20.0
Caldium Fluoride	2.0	0.5	12.0
Diamond, Carbon Type IIA	0.5	2.0	20.0
Silicon	2.5	1.1	11.0
Zinc Sulfide	2.0	0.49	13.0
Gallium Arsenide	0.5	1.0	19.0
Germanium	1.5	1.8	20.0
Lithium Fluoride	10.0	0.11	8.0
Sodium Chloride	10.0	0.12	13.0

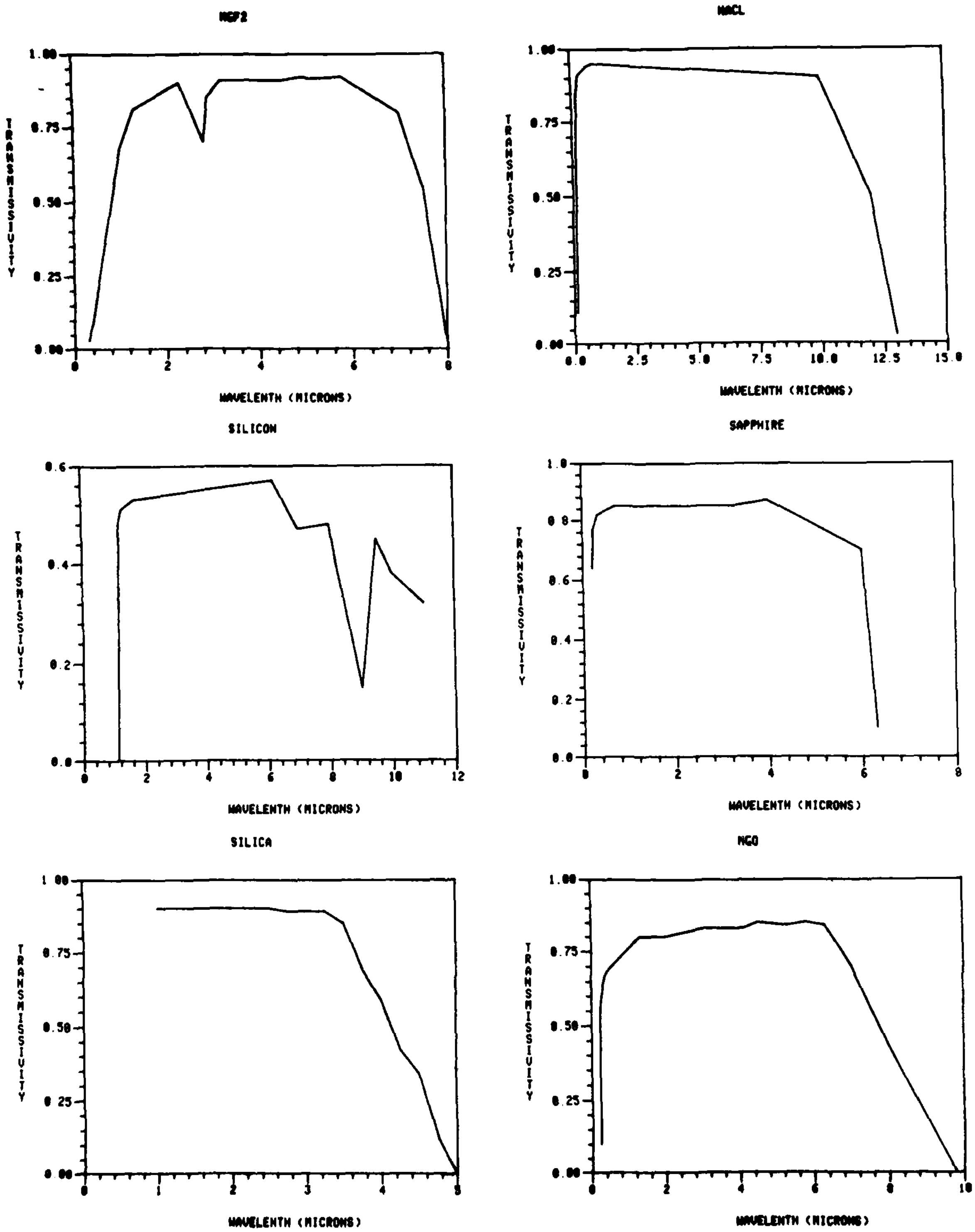


Figure 2.2 Sample Transmissivity Curves Employed in the OPTICS MODULE.

2.4.3 MODULATOR MODULE

The MODULATOR MODULE permits the user to select one of three methods of "modulating" the incoming signal. These methods are given below together with the required input data for each method.

CHOPPER

ODS code word = CHOPPER

FREQUENCY	-----	Chops per second with a 50% duty cycle and a sinusoidal output

CIRCULAR VARIABLE FILTER

ODS code word = CVF

SCAN PERIOD	-----	Time, in seconds, for the CVF to move from the upper wavelength to the lower wavelength
HALFWIDTH	-----	Halfwidth function of the filter which specifies the CVF bandpass for a given wavelength. It represents 1/2 the distance between those wavelength points at which the filtered signal will be attenuated by a factor of 1/2. It is expressed as a percentage of the wavelength.
LOWER WAVELENGTH	-----	The lower wavelength limit of the CVF in microns
UPPER WAVELENGTH	-----	The upper wavelength limit of the CVF in microns

FOURIER TRANSFORM SPECTROSCOPY

ODS code word = FTS

CHARACTERISTIC WAVELENGTH	-----	Microns, should be reasonably close to other wavelengths

2.4.4 DETECTOR MODULE

The DETECTOR MODULE performs two functions: 1) it provides a relative output which is a function of the wavelength of the incoming radiation (through D*), and 2) provides a frequency response function. All of the required information is stored in the computer and can be selected through the appropriate detector designation. Detector characteristics currently stored in the computer are given in Table 6. Figure 2.3 provides sample D* curves.

TABLE 6

Characteristics of Selected Detectors

DETECTOR	TEMPERATURE (Kelvin)	WAVELENGTH (microns)	TIME CONSTANT (seconds)
PbS	77.	0.5- 4.75	5.0×10^{-3}
PbS	193.	0.5- 4.0	3.0×10^{-3}
PbS	298.	0.5- 3.0	3.5×10^{-4}
PbSe	77.	1.0- 6.5	8.0×10^{-5}
PbSe	193.	1.0- 7.0	5.0×10^{-5}
PbSe	298.	1.0- 4.75	2.5×10^{-6}
Si	78.	0.575- 1.075	1.75×10^{-6}
Si	298.	0.4- 1.15	1.0×10^{-8}
InSb	77.	1.0- 5.5	6.0×10^{-7}
HgCdTe	196.	2.0- 4.4	1.1×10^{-6}

2.4.5 PREAMP/AMPLIFIER MODULES

The PREAMP/AMPLIFIER MODULES permit the user to select one of four supplied filter pre-amps (low pass, high pass, band pass, and band rejection), a user supplied response function, and the supplied data file where the amplifiers are described by poles and zeroes. This module uses the time step selected in the SOURCE module.

The amplifier modules require different inputs depending on which amplifier type is chosen. The various input requirements are discussed in general below.

For the filter amplifiers indicated in Figure 2.4 only the attenuation of filter (in dB) and two frequencies, labelled ω_1 and ω_2, are required. No time

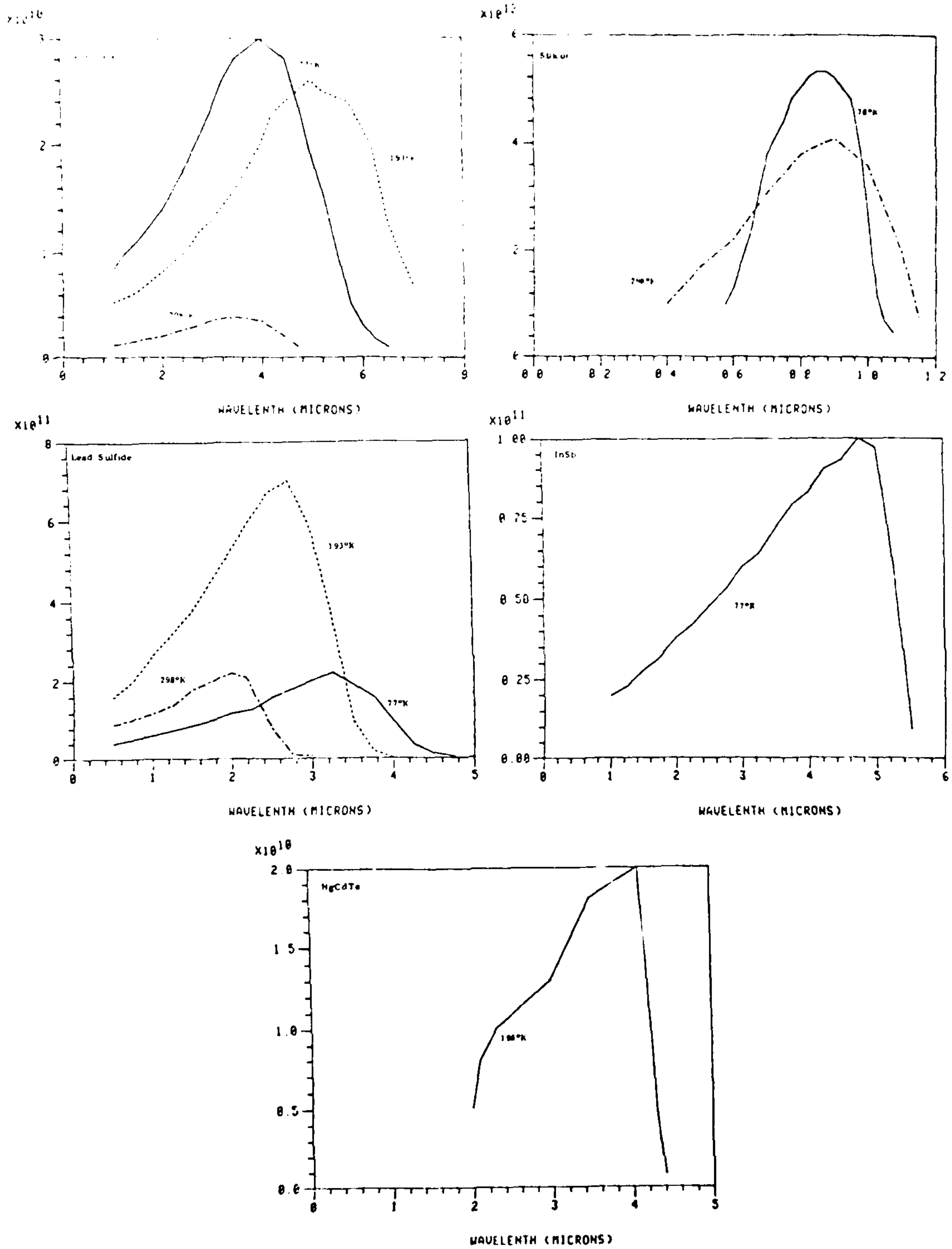


Figure 2.3 Sample Detectivity (D*) curves contained in the Data Base for the DETECTOR MODULE.

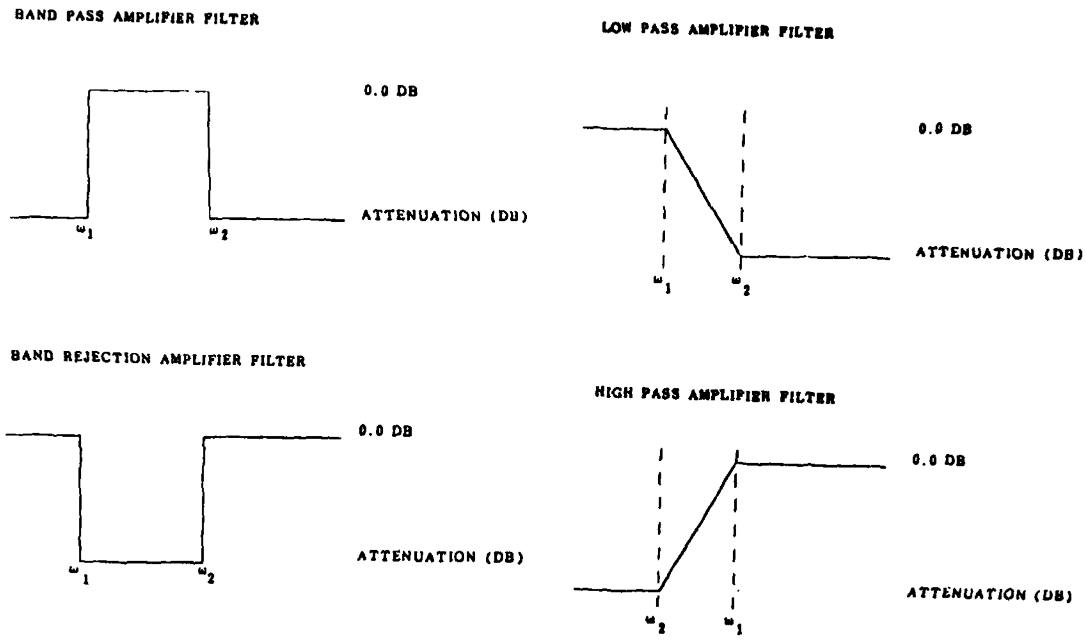


Figure 2.4 Characteristics of Filters Employed in PREAMP/AMPLIFIER MODULES.

parameters are necessary as the length of the response function is limited to 512 points.

The filter amplifier response functions are generated directly, while those described by poles and zeroes require use of the Heaviside function. The general form of the Heaviside function is,

$$\frac{P(S-Q_1)(S-Q_2)\ldots\ldots\ldots\ldots\ldots\ldots(S-Q_N)}{(S-W_1)(S-W_2)\ldots\ldots(S-W_{M-1})(S^2-2\xi W_M+W_M^2)}$$

where

N = number of zeroes
M = number of poles and $M > N$
Q = zeroes
W = poles
P = a multiplicative prefactor
ξ = the multiplicative factor in the quadratic term

Note: If $\xi = 1$, then the quadratic term becomes a multiple pole term of order 2. If there is no quadratic term, ξ should have the value of zero.

At the present time, the maximum number of poles allowed is 7, and, therefore, the maximum number of zeroes is 6. This is a minor constraint on the operation of the ODS code and could easily be modified. No poles of zero value are allowed.

It should be noted here that all amplifier response functions are responses to the unit impulse and that all time parameters are expressed in seconds. Any user generated response function must conform to these limitations.

3. MATHEMATICAL FORMULATION EMPLOYED IN SELECTED MODULES

In this section we will present in detail the mathematical formulation employed in certain modules. These modules include, optics, modulator, detector, and pre-amp/amplifier module. The source module requires no explanation.

3.1 Optics Module

The optics module performs two functions. It computes the transmissivity of the optical material/filters or the transmissivity of an etalon. Then, it multiplies the incoming signal produced by the source module by the computed transmissivity.

3.1.1 Optical Filter Material

The data file ODSOPT.INP contains a number of filter material as explained in Section 2.4.2. The transmissivity for each of these materials as a function of wavelength is based on a certain characteristic filter thickness as provided in the table. The transmissivity at other thicknesses is computed by the relation

$$\tau_2 = [\tau_1]^{x_2/x_1}$$

where τ_2 equals transmissivity for second thickness, τ_1 equals transmissivity from table, x_2 equals thickness of materials and x_1 equals thickness of material obtained from table. This relation is a direct extension or direct consequence of Beer's law. In developing this relation we have provided no shift in the transmissivity due to the angle of the incoming radiation.

3.1.2 Etalon

The etalon transmission characteristics are computed on the basis of the equation

$$\tau. = \frac{\tau_o}{1 + \frac{2(\lambda-\lambda_0')^2}{\Delta\lambda_{0.5}'}}$$

where τ_o is the centerline transmissivity at wavelength, λ_o, and $\Delta\lambda_{0.5}$ is the full width at half maximum transmissivity. The prime values represent the shifted center of the etalon and change in $\Delta\lambda_o$ because of the non-normal incidence of the incoming radiation. The shifted values are given by

$$\lambda_0' = \lambda_0 \left[1 - \frac{\theta^2}{2\mu^2}\right]$$

$$\Delta\lambda_{0.5}' = \Delta\lambda_{0.5}\left[1 + \left(\frac{\theta^2\lambda_o}{\mu^2\Delta\lambda_{0.5}}\right)^2\right]^{\frac{1}{2}}$$

where θ is the displacement of the incoming radiation from normal incident and μ is the effective index of refraction of the material in the filter (Ref. 3). Typical values of μ for the ultraviolet, visible, and infrared are 2.0, 2.35, and 5.0 respectively (Ref. 4-6).

The use of the formulation above does not permit a decrease in the centerline or peak transmissivity for non-normal incident radiation. This decrease in peak transmissivity is a function of many factors including λ_o, $\Delta\lambda_{0.5}$, θ and μ. However, in limiting the angle from normal incidence to only a few degrees, typically less than 5° the change in peak transmissivity is not severe.

3.2 Modulator Module

The modulator module performs three rather separate functions. The first function is that of a simple chopping wheel employed to change an essentially DC infrared radiation input into an AC signal for the detector and amplifier modules. The circular variable filter portion of the modulator module provides a time dependent signal which is based on the wavelength of the incoming radiation and the characteristics of the circular variable filter. The Fourier transform spectroscopy (FTS) routine simulates the output of an interferometer as a function of time for a number of different wavelengths.

3.2.1 Chopper

The chopper function simply multiplies the incoming signal from either the optics module or the source module by a sinusoidal time varying function which has values ranging from 0.0 to 1.0. The user simply specifies the frequency of chopping. The output of the chopper routine is given as

$$I_o(t) = I_i(t) \sin (2\pi ft)$$

where $I_o(t)$ and $I_i(t)$ are the output and input intensities, t is time, and f is the chopping frequency (Hz).

3.2.2 Circular Variable Filter

The circular variable filter routine processes a time varying input signal with a time varying filter function going from a lower wavelength, λ_1, to an upper wavelength, λ_2, in a period, T. Functionally, this may be represented by

$$I_{o,\lambda}(t) = I_{i,\lambda}(t)\ \mathrm{CVF}(t, \lambda_1, \lambda_2, \lambda, \Delta\lambda_{0.5})$$

The CVF function represents a many valued array which is computed on the basis of the lower and upper wavelengths and the response halfwidth of the CVF. The response halfwidth is based on a percentage of the wavelength. For instance, a 3% resolution is given as

$$\Delta\lambda_{0.5} = 0.03\ \lambda$$

The spectral response of the CVF is determined by employing a Gaussian profile of halfwidth $\Delta\lambda_{0.5}$. Thus,

$$CVF = e^{(0.694\ (\lambda-\lambda_o)^2/(\Delta\lambda_{0.5})^2)}$$

where λ is the wavelength of the incoming signal and λ_o is the time varying wavelength position of the CVF as it moves linearly in time from λ_1 to λ_2. Thus,

$$\lambda_o = (\lambda_2 - \lambda_1)\ (\frac{t}{T} - N) + \lambda_1$$

for $0 \leq \frac{t}{T} \leq 1$ where T is the time required to move from λ_1 to λ_2 (the CVF repetition rate). Of course, for $t > T$ the ratio t/T is suitably adjusted by the number of cycles of the CVF since $t = 0$. In the equation this is given by N.

It should be noted that the entire wavelength range of the CVF is divided into 1024 points in the computer. The limitations of 1024 points is due to the fact that the computer code was designed to operate on a mini computer. If the code should become operational on a much larger computer or one with virtual memory, then the number of points which can be used in the CVF can be expanded to any multiple of two. Since the current limitation is 1024 points the user should be very careful in selecting the filter halfwidth so that sufficient spectral resolution may be obtained over the entire wavelength region of the CVF. For instance, if the wavelength range of the CVF is from two to five microns, then the wavelength region will be divided into wavelength intervals of 0.0029 microns. Such a spectral interval generally is sufficient for a CVF. However, if a very narrow filter bandwidth is chosen for the spectral resolution, as defined by the halfwidth, then the wavelength span of the CVF should be reduced accordingly to provide the proper spectral resolution.

3.2.3 Fourier Transform Spectroscopy (FTS)

Figure 3.1 illustrates the typical mirror arrangement employed in an interferometer of a type generally used in FTS. The mirror M_1 moves back and forth providing an interference pattern at the detector

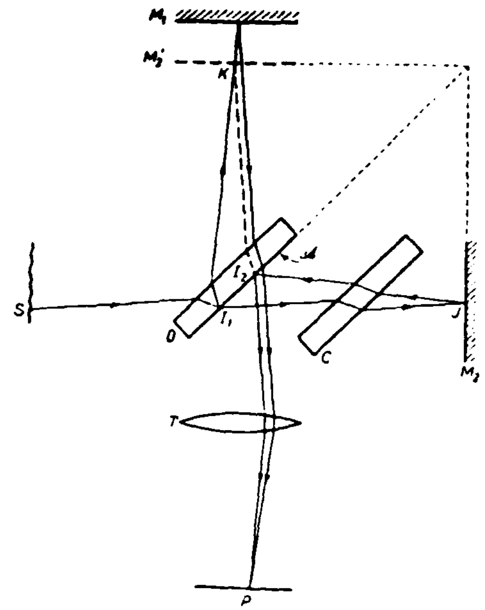


Figure 3.1 A Typical Interferometer

The interference pattern is given by the equation

$$I_o(t) = I_1(t) + I_2(t) + 2\sqrt{I_1 I_2}\cos(\theta(t))$$

where I_1 and I_2 are the intensities from mirrors M_1 and M_2 as perceived at the detector and $\theta(t)$ is the phase difference due to the difference in path length traveled by the two rays. In the case where $I_1 = I_2 = I_i/2$

$$I_o(t) = 2\, I_i(t) \cos^2 \frac{\theta(t)}{2}$$

It should be noted that I_i is the incoming intensity. In this formulation we have ignored the reflectivities of the mirrors and the transmission of the splitter plate and the compensating plate.

The phase difference, $\theta(t)$, is given by the relation

$$\theta(t) = 2\pi \frac{D(t)}{\lambda}$$

where $D(t)$ is the time varying difference in paths that the two rays travel. In normal FTS operation, the user has control over the rate of change of the mirror position as well as the distance over which the mirror may move. In this computer code, allowing the user to select these parameters could produce an FTS output which is entirely meaningless, due to the limited array size available in a minicomputer. Thus, it was decided that the mirror should move in one direction for 1024 time steps. During this movement in one direction a certain characteristic wavelength, input by the operator, will produce exactly 64 fringes on the detector. In this way the computer forces a mirror displacement and time dependency which is consistent with an FTS output. Once these parameters have been determined by the computer employing the characteristic wavelength, the other wavelengths selected by the user are phased employing the predetermined FTS parameters. The net result is a typical FTS output spectrum.

3.3 Detector Module

The detector module essentially performs two functions. It multiplies the incoming signal by the D* appropriate for that wavelength and it provides a certain characteristic time dependency. The wavelength dependent D* is indicated in the table ODSDET.INP. The temporal dependency of the detector is embodied in a characteristic reseponse time, τ_R. The response of the detector to a unit impulse is given by the relation

$$e_o = e^{-t/\tau_R}$$

This general formulation for the detector module was decided after examining the temporal behavior and frequency dependence of a wide number of detector materials. Although it does not exactly describe the temporal behavior of each individual material, it does provide a rather uniform formulation of the time dependency of each of the detector materials.

3.4 Preamp/Amplifier Module

The preamp/amplifier module performs three distinctly different types of operation, each of which produces a response to a unit impulse which then is employed in the convolution routine. The first type of operation employs a generalized digital filter which can provide low pass, high pass, band pass, and band rejection response functions. These were discussed in Section 2.4.5.

The second type of operation employs basic electrical circuit analysis and is based on user definition of the circuit in terms of poles and zeroes. The pole-zero response function is analyzed employing Heaviside techniques. The third type of operation employs a user supplied "gain" curve or response function in the frequency domain.

The response determined in the time domain is transformed to the frequency domain by employing an FFT. The resulting response function in the frequency domain is convolved with the FFT of the incoming signal. The inverse FFT of the results produces the output of the amplifier in the time domain.

3.4.1 Digital Filters

Digital filters, as employed in this section, are constructed in the frequency domain. The inverse FFT of the filter provides the response function in the time domain. Next, the complex FFT is taken off the time domain response function and used in the convolution routine. These seemingly unnecessary steps are required to preserve the phase of the incoming signal.

3.4.1.1 Low Pass and High Pass Filters

The algorithm employed in the low pass filter routine is quite simple. For frequencies less than a characteristic frequency, ω_1, the signals are passed unattenuated. For frequencies greater than another characteristic frequency, ω_2, the signals are passed after they have been attenuated an amount ATTEN given in decibels. For frequencies between ω_1 and ω_2, the signals are attenuated by an amount based on a linear interpolation between ω_1 and ω_2. High pass filters operate in the reverse fashion to the low pass filters described above.

3.4.1.2 Band Pass and Band Reject Filters

Band pass filters operate in a manner very similar to the low pass and high pass filters. The band pass is defined by the frequencies ω_1 and ω_2. Between these two frequencies signals are passed unattenuated. Outside these frequencies the signals are attenuated by an amount ATTEN.

3.4.2 Heaviside Operation

The response functions, $R(s)$, of many amplifiers can be described by a series of poles and zeroes, where the number of poles exceeds the number of zeroes. These poles and zeroes are often expressed as a polynomial of the form

$$R(s) = \frac{Z(s)}{P(s)}$$

where $Z(s)$ is the polynomial of zeroes
and $P(s)$ is the polynomial of poles

Response functions of this type can be analyzed in a straightforward manner by using the Heaviside theorems as described in Ref. #7, which is closely followed here.

For example, for an amplifier with 2 zeroes ($z_1 = 0$, $z_2 = -4$) and 4 pole terms (the last being a quadratic and poles 2 and 3 being equal), then $R(s)$ would look like:

$$R(s) = \frac{(s-z_1)(s-z_2)}{(s-p_1)(s-p_2)^2(s^2-\xi p_4 s+p_4^2)}$$

ξ is a constant term

This function contains all of the basic forms handled by the Heaviside theorems: single linear root $(s-p_1)$, multiple linear root $(s-p_2)^2$, and single quadratic root $(s^2-2\xi p_4 s+p_4^2)$.

The contribution to $R(t) = \mathcal{L}^{-1}\left[\frac{Z(s)}{P(s)}\right]$ made by a single linear term $(s-a)$ is given by

$$\frac{Z(a)}{Q(a)} e^{at}$$

where a = the pole in the single linear term being considered and where $Q(a)$ is the product of all the factors of $P(s)$ except the $(s-a)$ term. Therefore, for this example if

$$z_1 = 0, \; z_2 = -4$$

$$P_1 = -2 \;\; P_2 = -1, P_4 = \sqrt{2} \text{ (with } \xi = -1/\sqrt{2})$$

then

$$R(s) = \frac{s(s+4)}{(s+1)(s+1)(s+2)(s^2+2s+2)}$$

$$= \frac{s(s+4)}{(s+1)^2(s+2)(s^2+2s+2)}$$

here

$$Z(s) \quad = s \; (s+4)$$

and

$$Q(s) \quad = (s+1)^2 \; (s^2+2s+2)$$

evaluating

$Z(s)$ and $P \; (s)$ at $s = p_1$,

$$Z(p_1) \;\; = -2 \; (-2 + 4) = -4$$

$$Q(p_1) \;\; = (-2 + 1)^2((-2)^2 + 2(-2) + 2) = 2$$

Therefore, the contribution of the single linear pole to the overall temporal response function is

$$R_{p_1} \; (t) = -2 \;\; e^{-2t}$$

The contribution to $R(t) = \mathcal{L}^{-1} \; [\frac{Z(s)}{P(s)}]$ made by the multiple linear term $(s - a)^m$ is given by

$$e^{at} \; [\; \frac{\phi(a)^{(m-1)}}{(m-1)!} + \frac{\overset{(m-2)}{\phi} \; (a)}{(m-2)!} \;\; \frac{t}{1!} + \cdots + \frac{\phi'(a)}{1!}$$

$$\frac{t^{m-2}}{(m-2)!} + \;\; \phi(a) \;\; \frac{t^{m-1}}{(m-1)!} \;]$$

where $\phi(s)$ = quotient of $Z(s)$ and all the factors of $P(s)$ except $(s-a)^m$. Note that $\overset{(m-1)}{\phi(a)}$ denotes the $(m-1)^{th}$ derivative of $\phi(s)$ evaluated at $s = a$. Therefore, for

$$R(s) = \frac{s(s+4)}{(s+2)(s+1)^2(s^2+2s+2)} ,$$

$$\phi(s) = \frac{s(s+4)}{(s+2)(s^2+2s+2)} \quad \text{and since } m = 2,$$

$$\phi'(s) = \frac{2s+4}{(s+2)(s^2+2s+2)} - \left[\frac{s(s+4)}{(s+2)^2(s^2+2s+2)} + \frac{s(s+4)(2s+2)}{(s+2)(s^2+2s+2)^2} \right]$$

and

$$\phi\ (p_2) = -3$$

$$\phi'\ (p_2) = 5$$

and

$$R_{p_2}(t) = e^{-t}\ [5-3t]$$

The contribution to $R(t) = \mathcal{L}^{-1}\ [\frac{Z(s)}{P(s)}]$ made by the single quadratic term

$((s + a)^2 + b^2)$ is given by

$$\frac{e^{-at}}{b}\ (\phi_i \cos bt + \phi_r \sin bt)$$

where

ϕ_i is the imaginary part of $\phi\ (-a + ib)$

ϕ_r is the real part of $\phi\ (-a + ib)$

and $\phi(s)$ is the quotient of $Z(s)$ and all factors in $P(s)$ except the quadratic term. Therefore, for our example,

$$\phi(s) = \frac{s(s+4)}{(s+2)(s+1)^2}$$

and

$$(s+a)^2 + b^2 = s^2 + 2s + 2$$

and

$$a = 1$$

$$b = 1$$

$$\phi(-1+i) = \frac{(-1+i)(-1+i+4)}{(-1+i+2)(-1+i+1)^2} = -1 - 3i$$

$$\phi_r = 1, \ \phi_i = 3$$

therefore

$$R_{p_4}(t) = e^{-t}(-3 \cos t + \sin t)$$

Finally, the overall temporal response function is

$$R(t) = -2e^{-2t} + (5-3t)\, e^{-t} + e^{-t}(-3 \cos t + \sin t)$$

The ODS code computes the temporal value of this impulse response function in time increments selected by the user. Then the FFT of the response function is performed and all subsequent operations occur in the frequency domain (i.e., the FFT of the response function is convolved with the FFT of the incoming signal). At the end of the computations the inverse FFT is performed transferring the signal back to the time domain.

3.4.3 Gain Curve

This method of filter design is essentially a straightforward application of the fact that a filter transfer function and its impulse response are Fourier Transform pairs. In this program the frequency response of the desired filter is specified as a gain curve - i.e., in the frequency domain - and the resulting impulse response is derived from this transfer function.

The procedure is implemented as follows: first, the gain curve is converted from decibels to a linear scale of normalized magnitudes between 0 and 1. These magnitudes are then used as a set of weighting coefficients on the set of complex exponentials of unity magnitude between 0 and 2π. This results in a synthetic "Fourier Transform" which is then transformed back into the time domain by the inverse FFT. Finally, a Blackman window is applied to the time domain sequence in order to reduce the possible effects of truncation of the impulse response, and to improve the stability of the filter at peaks in the original gain curve.

4. ODS APPLICATIONS

The primary purpose of the ODS computer is the simulation of the temporal response of a wide range of electro-optical sensors. Therefore, considerably more effort was devoted to developing the proper temporal algorithms than wavelength sensitive functions. However, in order to evaluate a sensor in an elementary manner it is necessary that some attention be given to the wavelength of the incoming radiation. Thus, the computer code will consider the wavelength dependency of certain aspects of electro-optical sensor design. The manner in which this wavelength dependence is considered was discussed in Section 3. In this section we will present several typical applications of the ODS computer code. The actual manner in which the operator interacts with the ODS code is illustrated in the Appendix for each example given below. The Appendix contains the actual exchange between the operator and the ODS code. Additional examples are provided in the Program Users Manual (Ref. 1).

4.1 Test Case 3 - Program User's Manual

The primary purpose of this example is to illustrate the results obtained when a sinusoidal input signal is chopped and passed through a low pass filter amplifier with the response function given by

$$R(s) = C/(s + 490.2)$$

where C is a constant. For this application we employed the following modules

- o SOURCE MODULE provided the sinusoidal signal at 50 Hz and at a wavelength of 2.5 microns.
- o OPTICS MODULE provided the wavelength dependency of the sapphire window.
- o MODULATOR MODULE provided the chopper operation. The chopper rotated at 500 Hz.
- o AMPLIFIER MODULE provided the impulse response function indicated above. This is one of the responses contained in the ODS data base.

Once the amplifier was selected it is necessary that the time step for the computation be provided. The selection of the time step depends on two factors. First, the time step must be sufficiently small to provide an adequate representation of the impulse response. Second, the duration of the impulse response in the time domain must be of sufficient length that all of the necessary features of the response function are included. The final restriction is that the current ODS code employs 512 points in time to represent the response function. Therefore, the choice of time step and duration of the impulse response must be carefully selected. The ODS code includes in the data base for the amplifier functions a minimum duration and a maximum step size. For the amplifier above the maximum step size is 0.001 seconds and the minimum duration is 0.020 seconds. These were chosen through a trial and error procedure in which a number of simple input signals were examined employing a range of step sizes and response function duration.

Figure 4.1 illustrates the output from the chopper and indicates the basic sine wave input and the effects of chopping at 500 Hz. Figure 4.2 illustrates an expanded portion of the signal after it has been processed by the amplifier. It is obvious that the amplifier is too "slow" to provide a good representation of the chopper output signal. Figure 4.3 indicates 0.5 seconds of processed signal.

In this situation the operator would realize that the combination of the selected chopper speed and the low pass amplifier is not a good match. Therefore, the operator could either use a "faster" amplifier or a slower chopper speed.

4.2 Test Case 4 - Program User's Manual

This example illustrates the use of the ODS code to simulate a circular variable filter which was discussed in Section 3.2.2. For this computation, we employed a positive step input from the SOURCE MODULE and specified three wavelengths, 4.0, 4.2, and 4.4 microns, with relative intensities of 1.0, 2.0, and 0.5 respectively. To further illustrate how the ODS code functions we started and stopped each signal at different times. Thus, the signal at 4.0 microns started at 0.0 seconds and ended at 0.1 seconds. The signal at 4.2 microns started at 0.01 seconds and ended at 0.1 seconds. The third

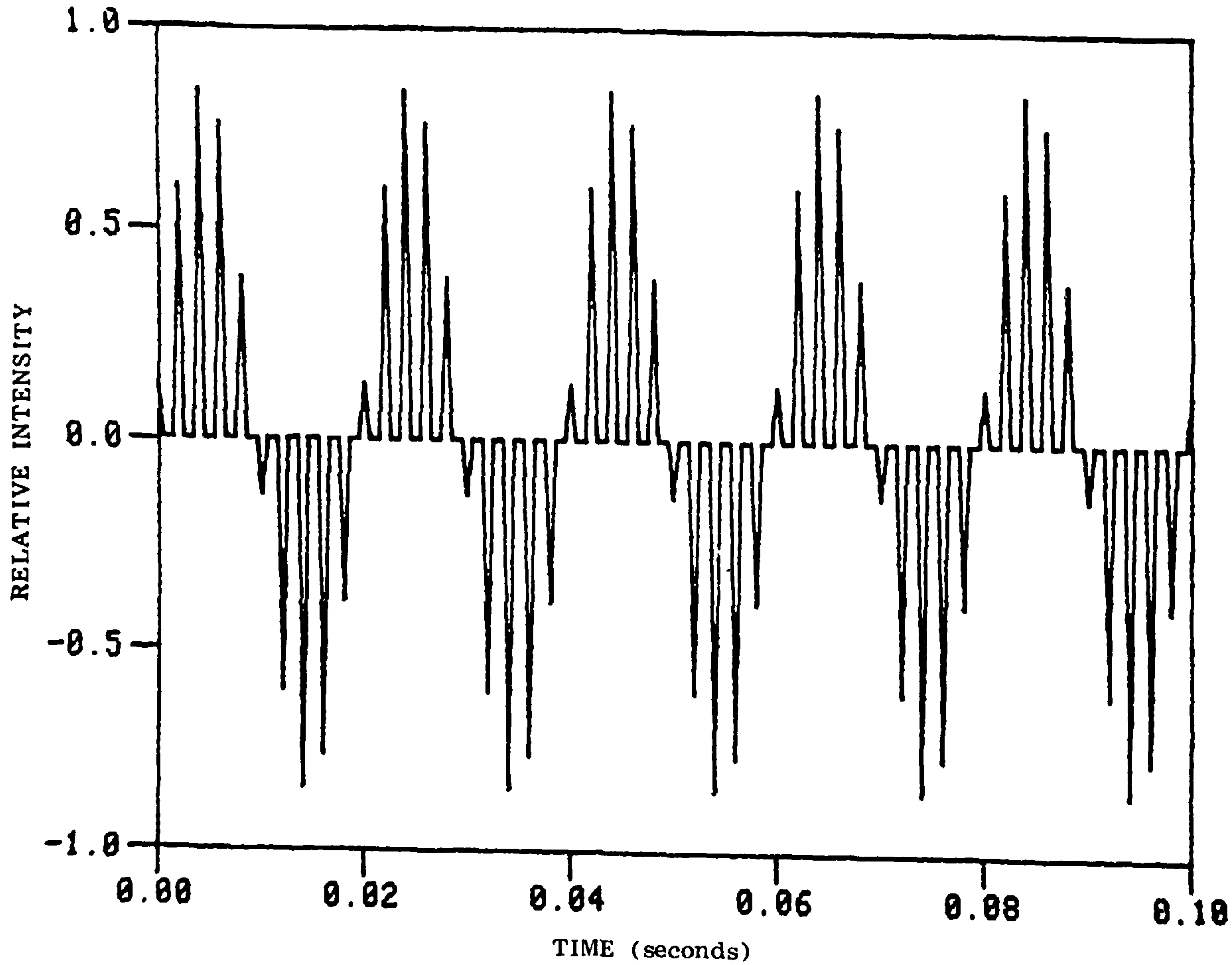


Figure 4.1 From Chopper Section of MODULATOR MODULE.

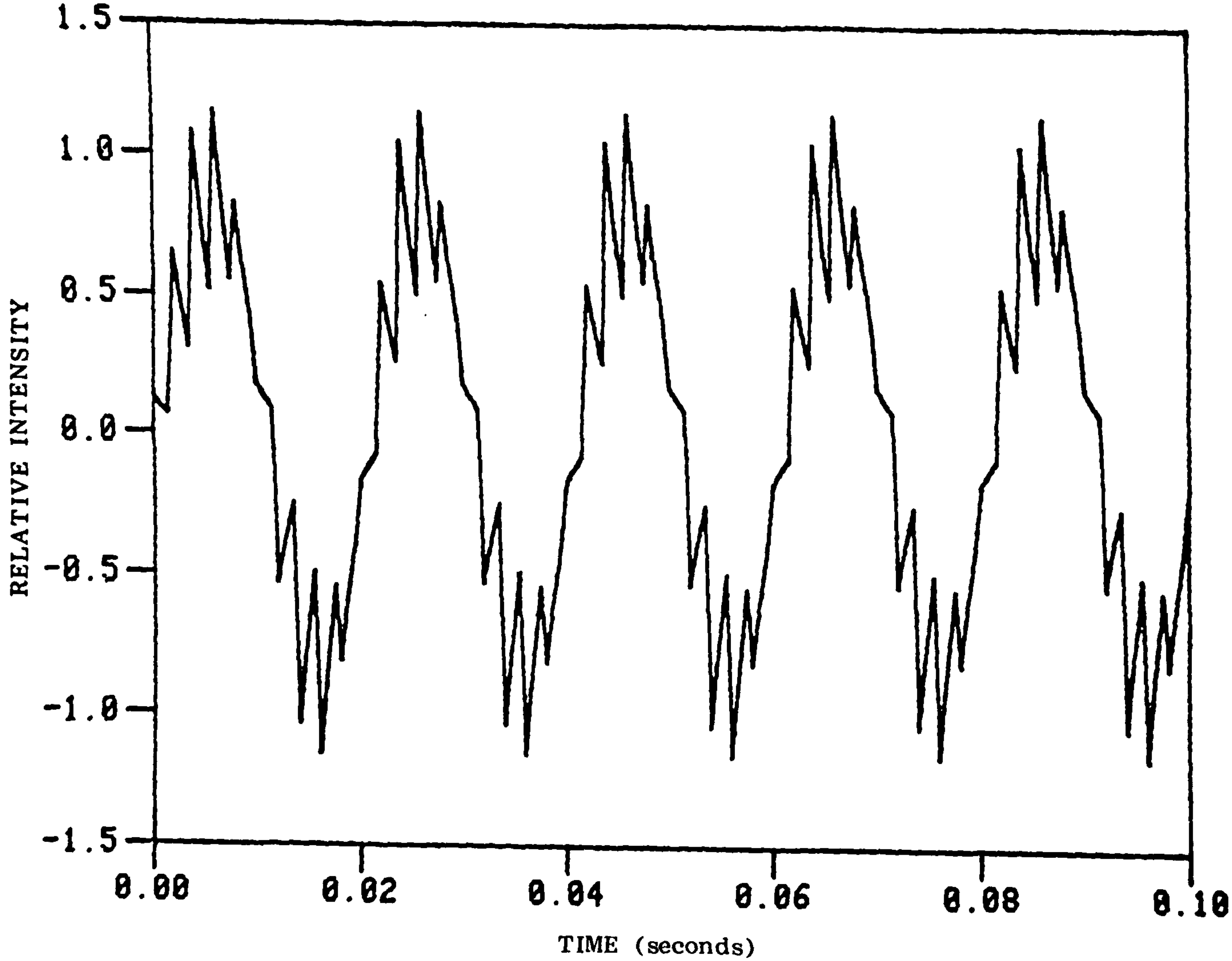


Figure 4.2 Portion of Output from Preamplifier.

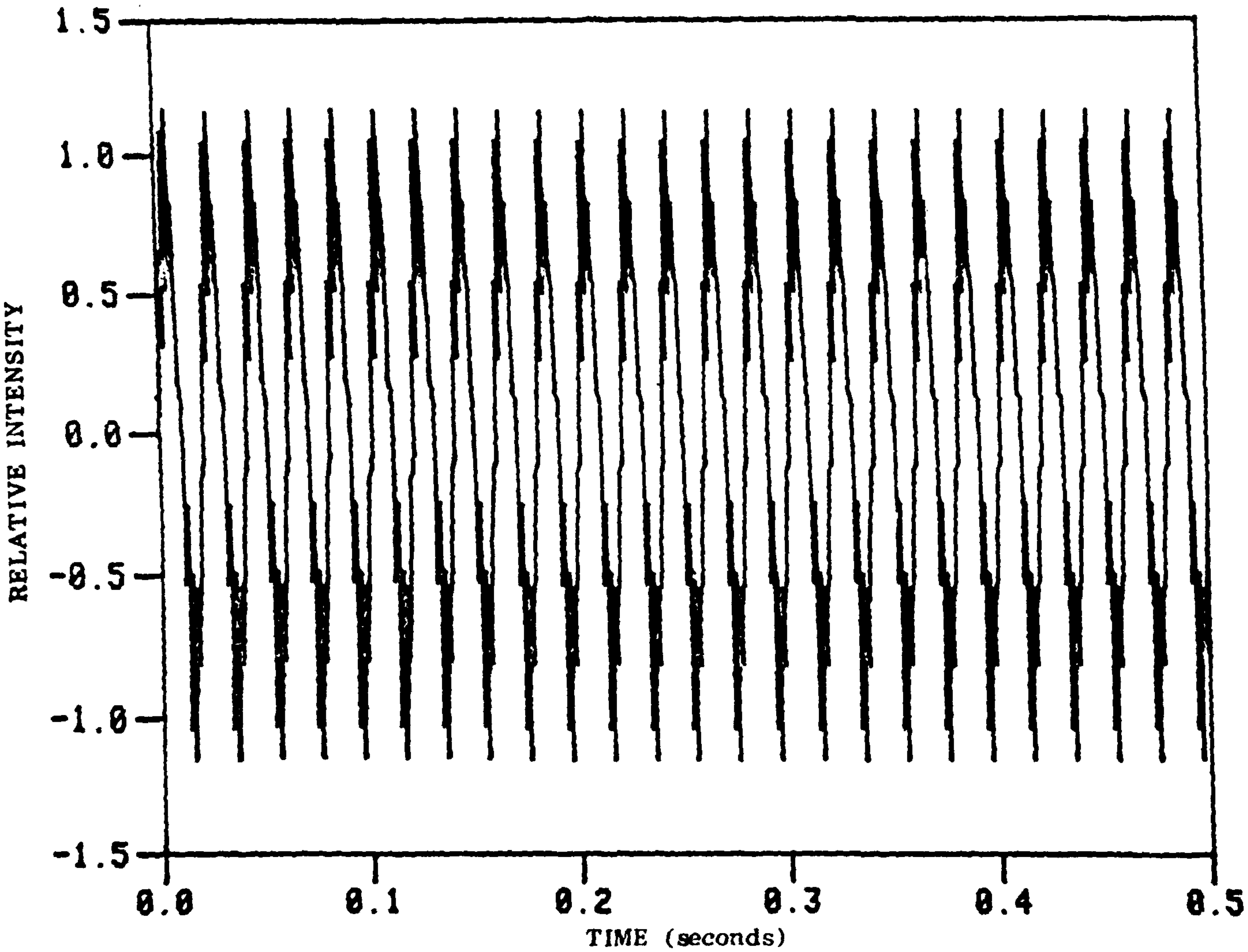


Figure 4.3 Entire Output of Preamplifier.

signal at 4.4 microns started at 0.02 seconds and ended at 0.1 seconds. It should be pointed out that the duration of the signal does not have to be a specific value: it can be a very large value. The ODS code will work on the signal in 1024 point segments.

The circular variable filter was chosen to provide 100 scans per second. In addition, the wavelength of the filter extended from 3.5 microns to 5.0 microns. The resolution of the filter was 2.0% of the wavelength. The output from the CVF section of the ODS code is shown in Figure 4.4. It should be noted that the CVF scans from high wavelength to low. The individual character of each wavelength is obvious in Figure 4.4.

The amplifier consisted of 2 poles and 1 zero with

$$R(s) = \frac{100.04(s + 617.28)}{(s + 628.93)(s + 500.0)}$$

The output of the amplifier is shown in Figure 4.5 which indicates that the frequency response is too low. The output obviously is distorted producing a substantial error in the relative intensities at the three wavelengths, although the position (wavelength location) of the peak intensities has not been altered.

4.3 Test Case 5 - Program Users Manual

This case illustrates the use of the Fourier Transform Spectroscopy part of the modulator module. Wavelengths of 4.0, 4.2, and 4.4 microns were selected. The amplitudes, start times, and signal duration were identical for all three signals. These signals were provided by the SOURCE MODULE. A lower wavelength of 3.9 microns was used to establish the necessary parameters for the FTS as described in Section 3.2.3. We also selected a detector material of INSB. The output from the detector is shown in Figure 4.6. The characteristic pattern of the FTS output is clearly observed.

This time a simple high pass (HP) filter was selected for the amplifier. The filter parameters were defined to have a rolloff frequency of 100 Hz and with an attenuation of 20 db at 50 Hz. All frequencies below 50 Hz were attenuated 20 db. The attenuation between 50 and 100 Hz is assumed to be a linear

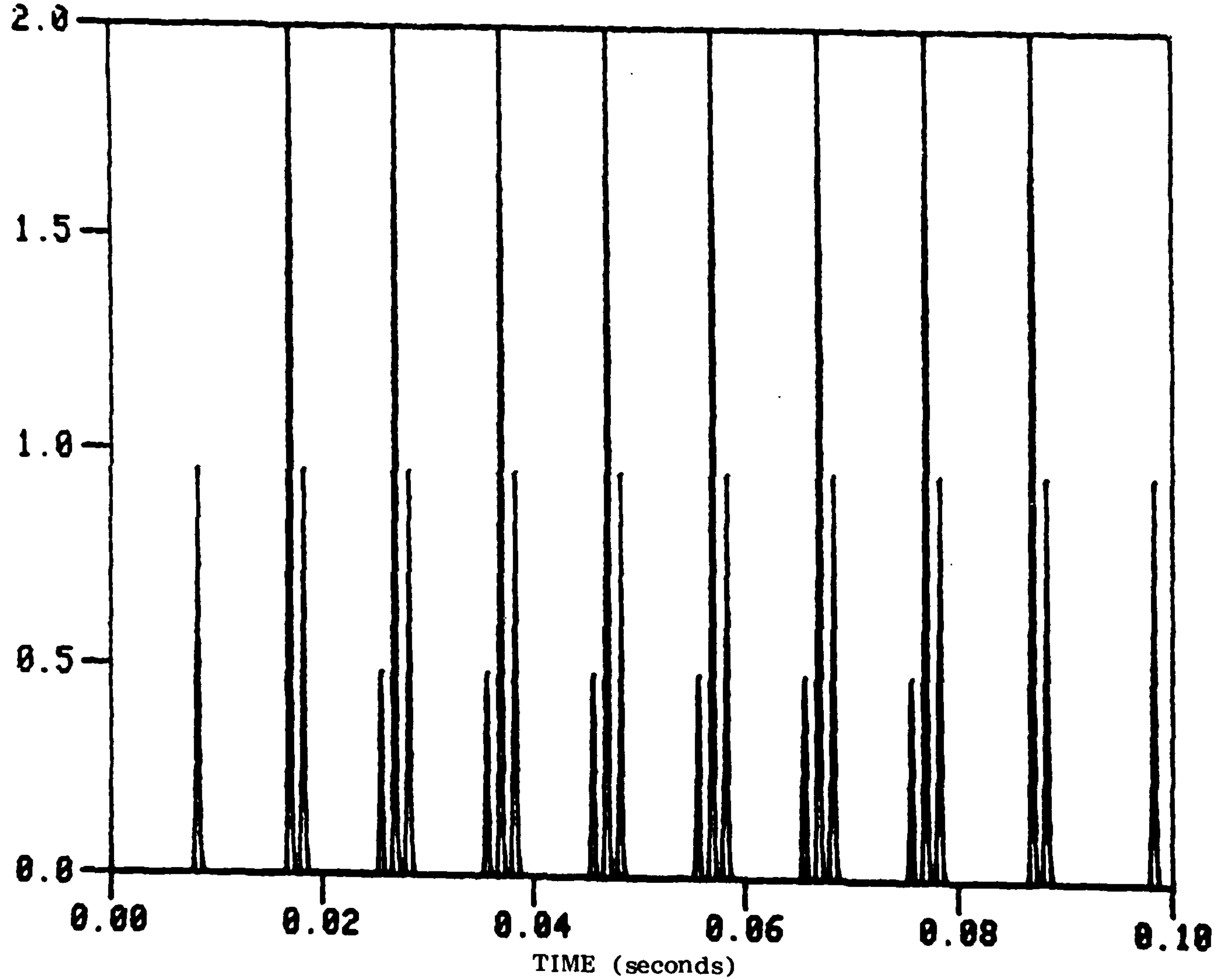


Figure 4.4 Output from Circular Variable Filter illustrating three separate wavelengths.

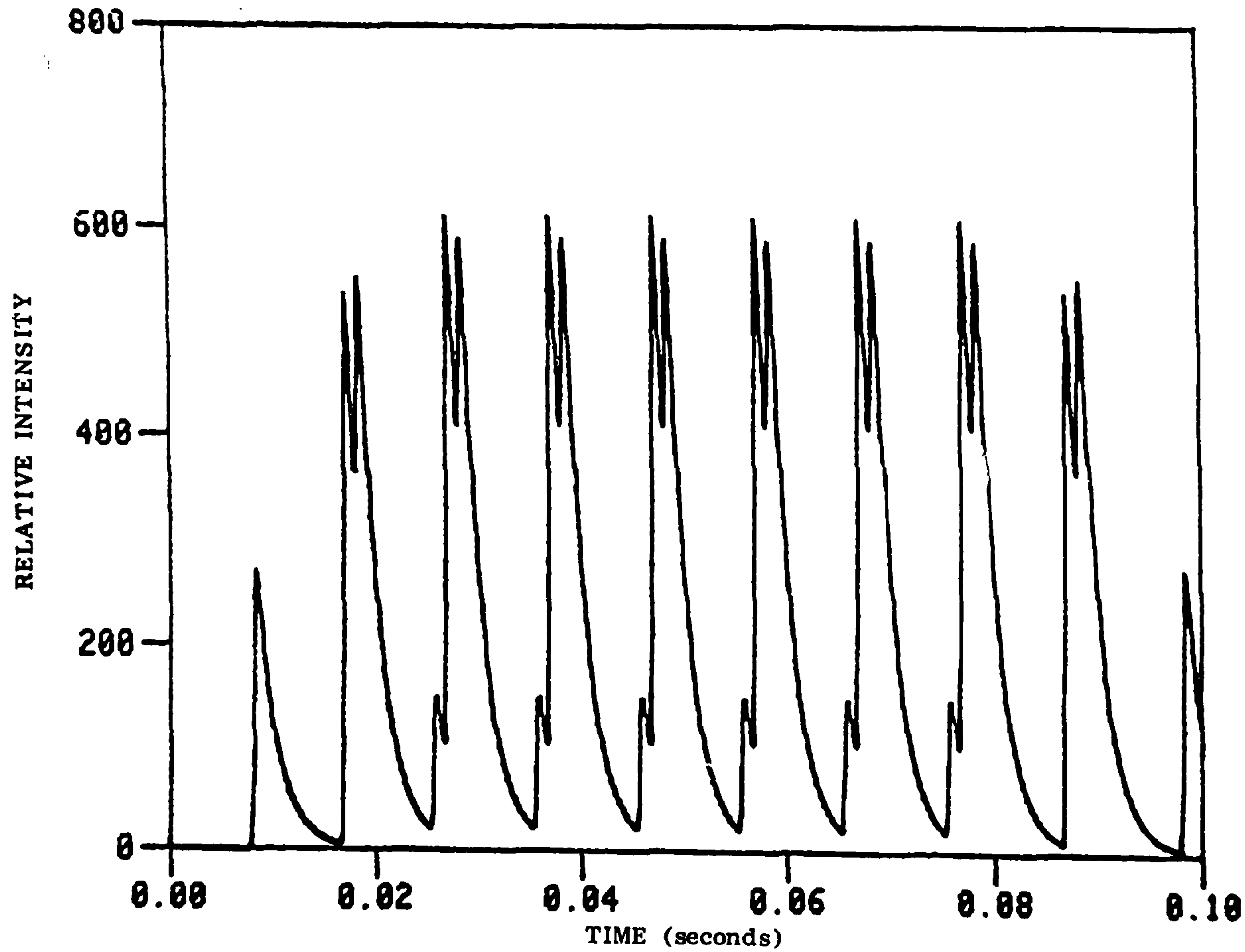


Figure 4.5 Output from Amplifier.

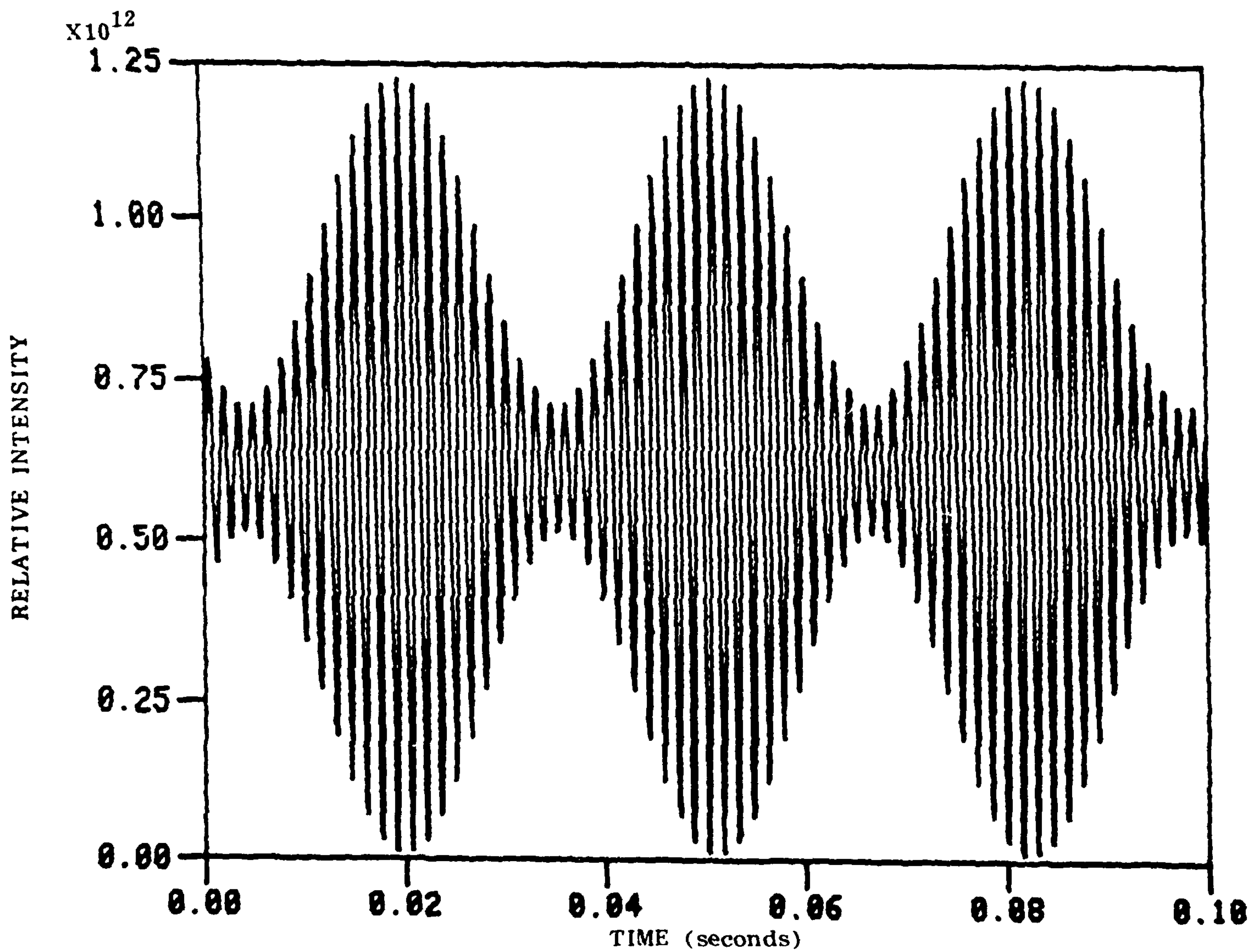


Figure 4.6 Output of Detector Module of Signal from FTS.

function. The output from the high pass filter is illustrated in Figure 4.7. Here the reproduction of the detector signal is quite good. However, the signal has been displaced in time due to the nature of the digital filter design. Normally, this is not a problem. However, if it becomes a problem only a minor change is needed in the computer code.

4.4 Test Case 6 - Program Users Manual

This example is probably more typical of how the ODS computer code may be employed. Here, a simple square wave is employed as the basic input signal. However, we have added some noise to the signal. Then we have employed an amplifier and a low pass filter, which acts like an integrator.

Figure 4.8 indicates the square wave and the associated noise. The preamp which we selected had one pole at 490.0 and no zeroes. The output from the preamp is illustrated in Figure 4.9 which clearly shows the "cleaning" due to the low pass nature of the preamp response function. Finally we passed the output from the preamp through a low pass filter with a rolloff frequency at 100 Hz and with an attenuation of 30 db for signals of 120 Hz and higher. The results of this process are indicated in Figure 4.10 where the clean nature of the signal is quite obvious.

4.5 TROUBLESOME PREAMP/AMPLIFIER TRANSFORMS

Although most transforms for conventional preamps and amplifiers can be handled by the ODS computer code, certain types of transforms cannot be adequately treated in the current version of the code. In Section 2.4.5 we indicated that the maximum number of zeroes and poles are 6 and 7 respectively. This is a very minor limitation and can be changed quite easily (Program Maintenance Manual, Ref. 2).

A particular class of transforms exist which would require a major modification to the code and possible operation on a computer with a memory of greater than 32 k words. This limitation concerns the magnitude of the various poles and zeroes in the transform and is a direct result of the limited number of points used in the ODS code to represent the time varying transform. As an example consider the transform

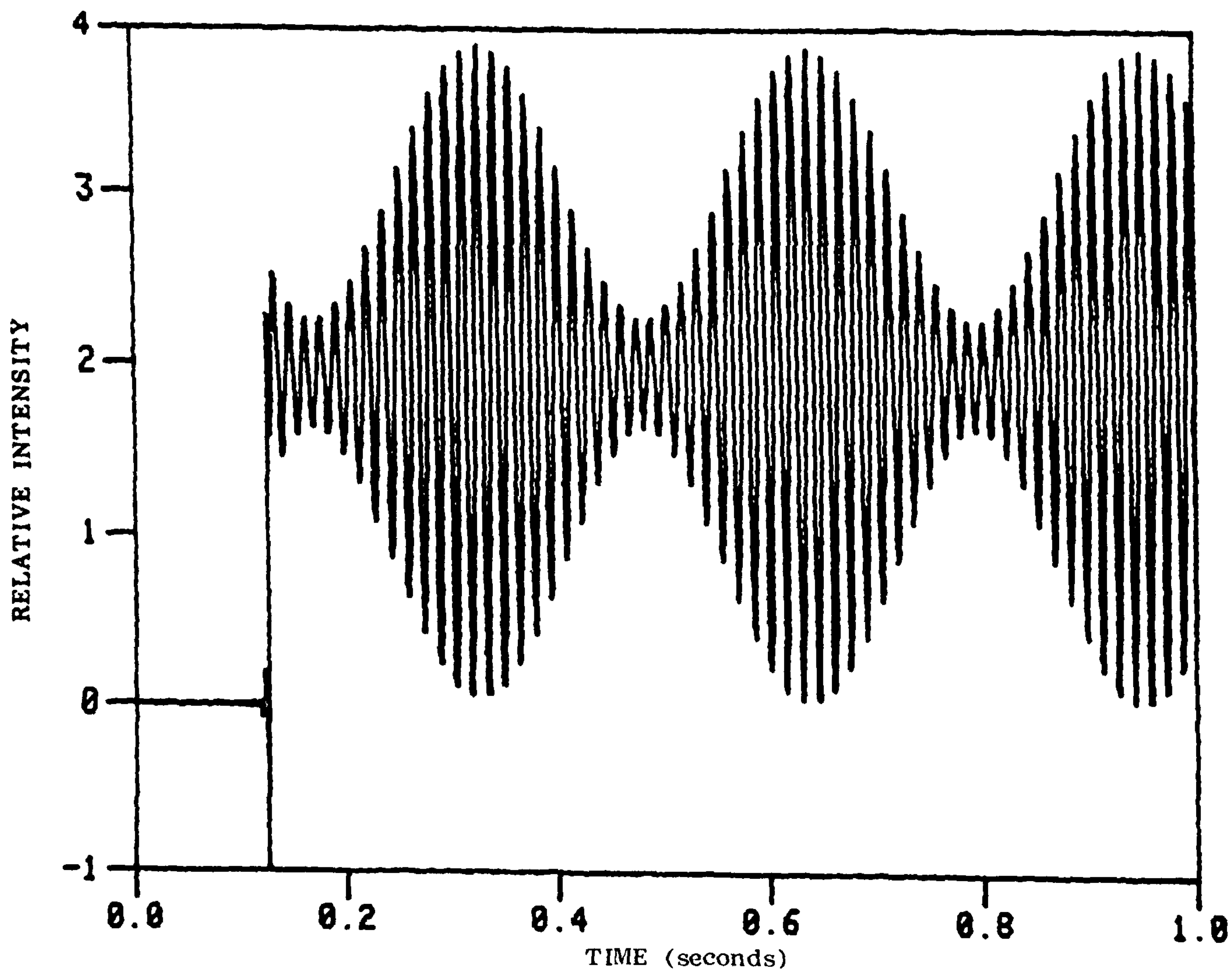


Figure 4.7 Effects of employing high pass filter on Signal given in Figure 4.6.

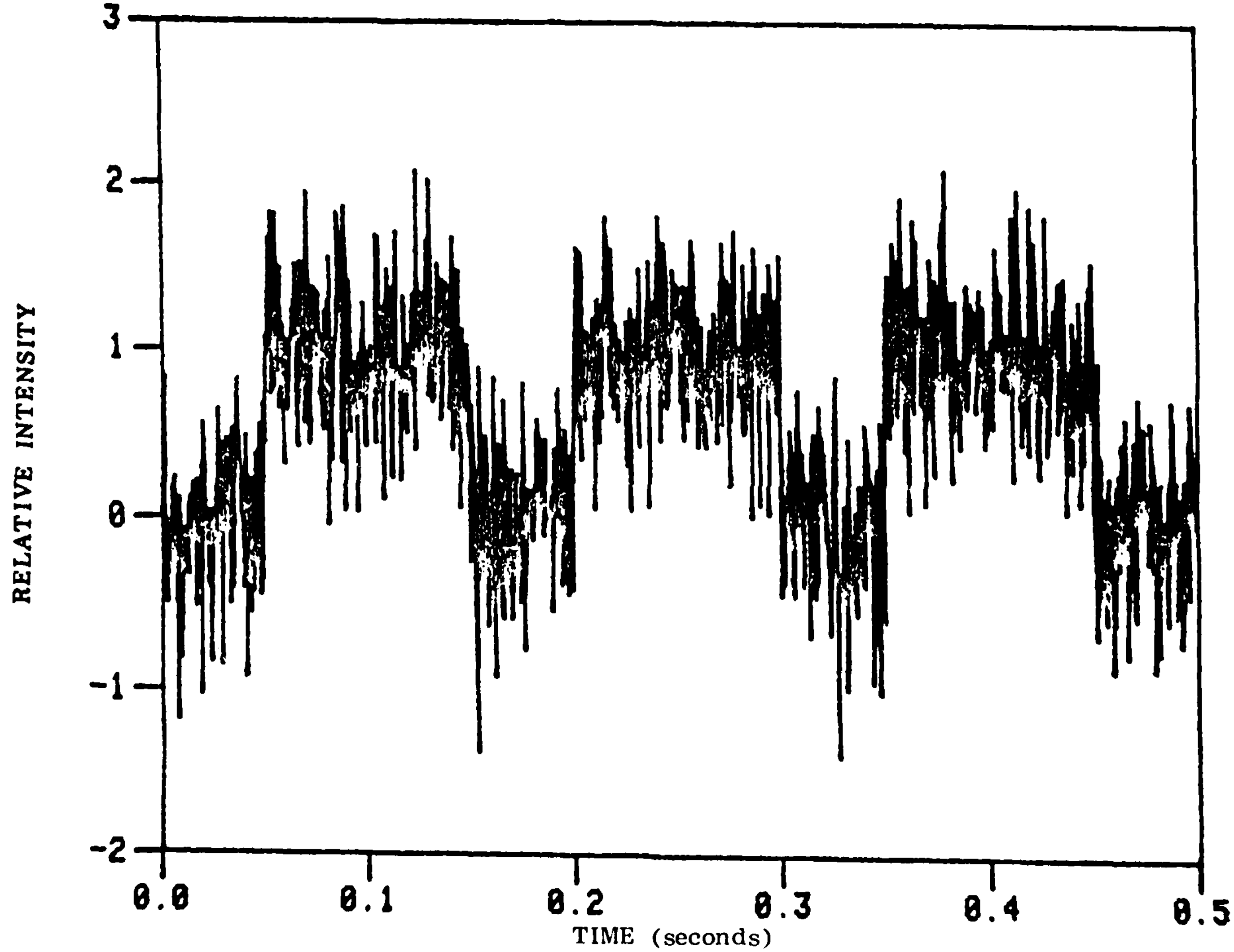


Figure 4.8 Source Signal illustrating effects of noise added to a square wave.

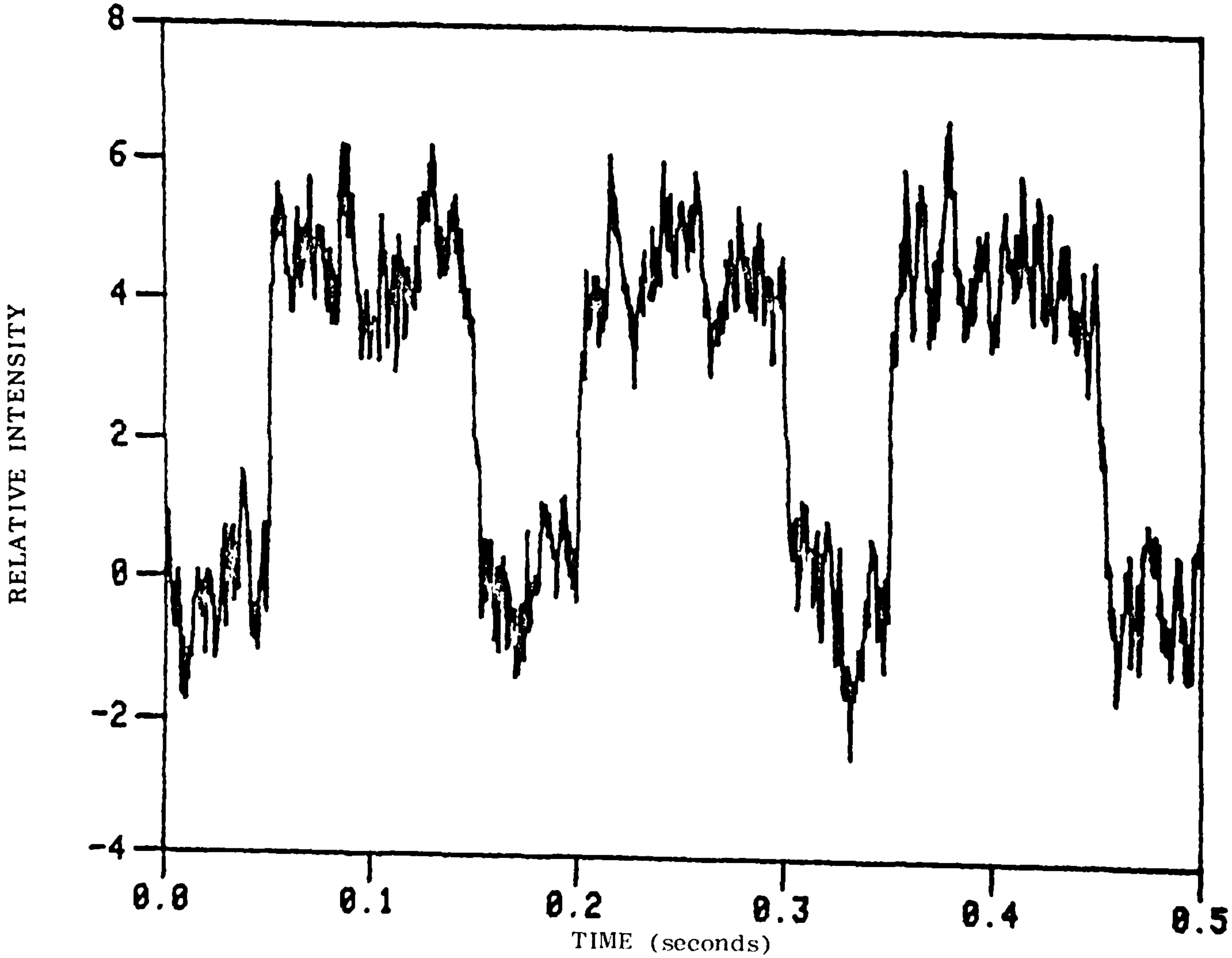


Figure 4.9 Output of Amplifier of input signal given in Figure 4.8.

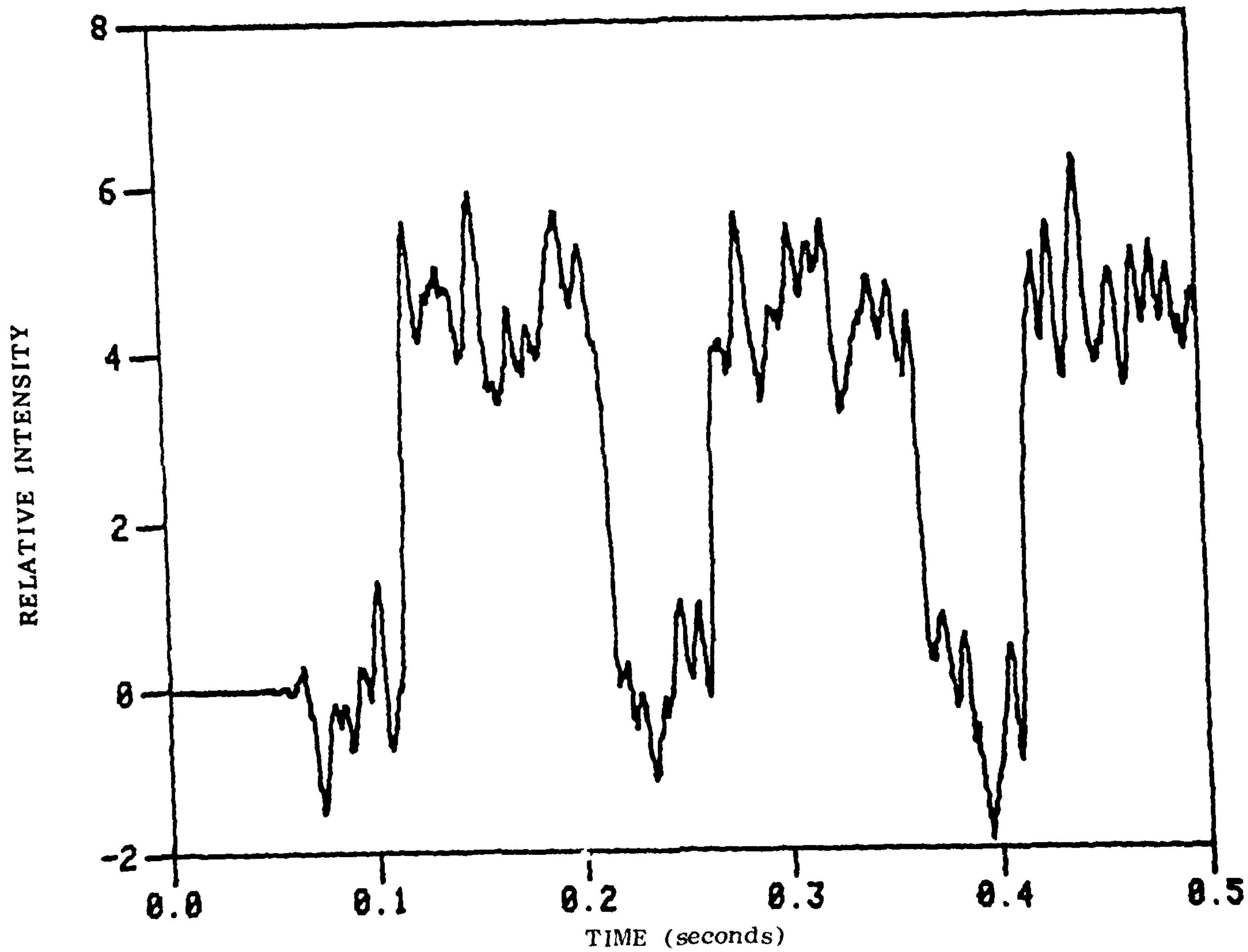


Figure 4.10 Effects of Low Pass Filter.

$$R(s) = \frac{s}{(s + 13.)\ (s + 13000.)}$$

It is virtually impossible to adequately treat this transform employing the algorithms currently used in the ODS code. The transform in the time domain is approximated by up to 512 time steps. With poles of greatly varying magnitude it is very difficult to properly represent the transfer function.

To circumvent this potential problem we have examined two possible solutions. First, the user may employ a very small step size and compute the response for just the larger pole. Then, employing a user generated program the temporal output can be adjusted to a larger step size. This step would be large enough to accommodate the lower pole. A second, more satisfying approach to this ODS code limitation is to consider the entire electrical circuit rather than element by element. In the problem illustrated above the circuit was followed by one with the transfer function given by

$$R(s) = \frac{1}{(s + 400.)}$$

Multiplying both transfer functions together to produce the overall transfer function of the system we obtain

$$R(s) = \frac{s}{(s + 13.)(s + 13000.)(s + 400.)}$$

We have indicated the gain curve for the overall system and that for the two pole portion of the system in Figure 4.11. It is quite obvious that the addition of the third pole at 400 rolls off the high frequency response faster than the 13,000 pole. We also have indicated the gain curve if we eliminate the troublesome pole at 13,000. Clearly, the response characteristics do not change significantly. Therefore, we can adequately represent the overall system with two poles; one at 13 and one at 400. It will be recommended in the next section that the ODS code be modified to provide for an alternate method of treating transfer functions with greatly separated poles.

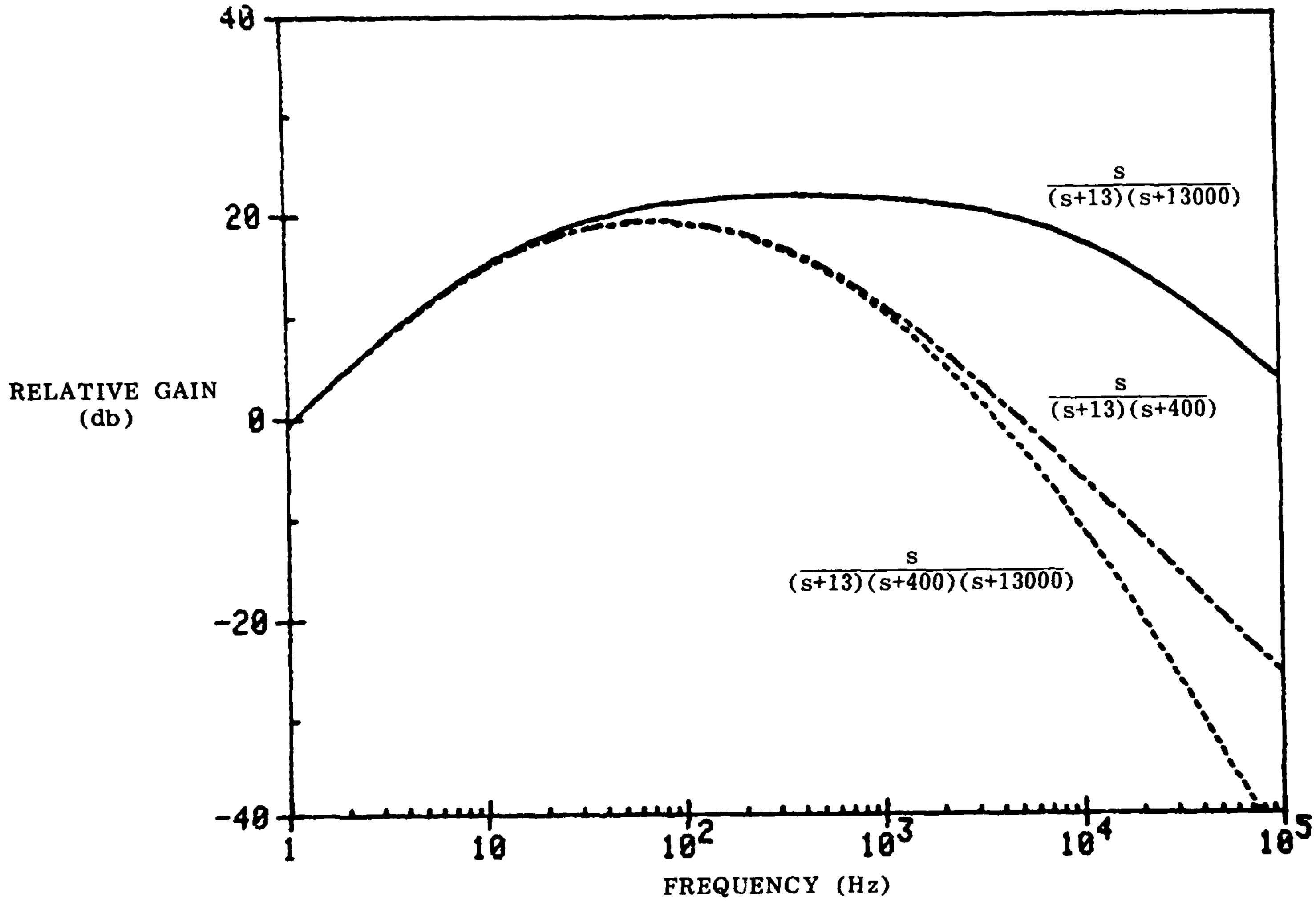


Figure 4.11 Gain Curves obtained through the use of Poles and Zeroes.

5. RECOMMENDATIONS

The current version of the ODS computer code provides the user with many approaches to examining the temporal response of electro-optical sensors. At the end of the effort we re-examined the approach we had taken during the development of the code and the discussions we had with the users. In retrospect we would have taken somewhat different approaches in treating certain aspects of the computer code. However, the actual approaches taken did provide for an adequate simulation of the temporal response of electro-optical sensors. At this point we believe that several modifications and extensions to the code would greatly enhance the ability of the code to treat a much wider range of electro-optical sensors and aid in the design of new sensors. In this section we will discuss each of the recommended modifications and extensions.

5.1 Overview of Modifications and Extensions

We have listed below the recommended changes in the current version of the ODS code:

- o Input signal and background in watts/cm^2/str
- o Add scintillation and attenuation to Atmospheric Module
- o Add elementary optical design package to Optics Module
- o Add a routine to perform a signal to noise analysis
- o Expand the number of points employed in the FTS routine
- o Add a wider range of detector materials and types
- o Add the ability to treat a much wider range of amplifier types including standard RLC circuits.

5.2 Signal and Background Input in Absolute Intensity Units

Since the current version of the computer code was directly primarily at the understanding of the temporal response of the sensor very little attention was given to the absolute intensity. Hence, although the code can produce a signal including noise of several types, the signal is not in absolute intensity units. Therefore, the user cannot determine if the signal he is trying to simulate might be too weak for the sensor to detect. This is particularly important with the detector module and the amplifier modules since the noise which may be produced by these modules is not added to the signal as it is processed.

This addition also requires updating the Optics Module to provide for entrance optics preliminary design. Thus, the user would have the ability to increase the diameter of the entrance optics if the signal is very weak.

5.3 Additions to Atmospheric Module

An important addition to the Atmospheric Module would be the ability to approximate the effects of atmospheric scintillation since it is one of the factors leading to laser signal attenuation, in addition to scattering by aerosols and absorption. A relatively simple model could be used to permit the user to estimate the effects of various levels of scintillation on the observed signal.

5.4 Additions to Optics Module

Currently the Optics Module contains transmissivities as a function of wavelength for a wide range of materials. A simple Beer's law relation is used to attenuate the incoming signal. The Optics Module should contain an elementary optics package which would enable the use to select a single lens or one of several types of reflecting optics. The user also could select coating for the optics. In addition, the routine would perform a computation to determine the "blur" circle formed by the converging rays. In this way the user would have some information concerning the field of view of the optics and the basic detector size (which is required for a signal to noise analysis).

5.5 Signal to Noise Analysis

The addition of a signal to noise analysis to the ODS code would greatly expand the possible applications of the code. This analysis must include the radiation "noise" from the many surfaces inside the radiometer, including the lens and filter surface. In addition, the analysis must consider the detector noise which is a function of detector temperature, D*, area, and frequency bandwidth of the system. Finally, the analysis must include the input noise level of the preamplifier.

This use of this signal to noise analysis could provide preliminary evaluation criteria for sensor design or performance. Of course, the analysis must include the optical collecting area as described in Section 5.4. The background noise, usually an important aspect of the signal to noise analysis, was discussed in Section 5.2.

5.6 Expanded Fourier Transform Spectroscopy

At the present time the spectral resolution capable with the FTS routine of the ODS code is limited by the number of points which can be used to represent the motion of the mirror. This part of the code must be expanded, either using virtual memory or a larger computer.

5.7 Additional Detector Material and Types

The ODS code assumes that the output from the detector module is directly proportional to the magnitude of the input signal to that module. Such a relationship includes most detector types. However, detector types which do not have a direct relationship with the intensity are not considered. For instance, certain detectors respond like a differentiator to a change in intensity or polarization. The ability to treat this type of detector should be incorporated into the ODS code.

5.8 Wider Range of Preamp/Amplifier Types

In developing the ODS code we assumed that all amplifier responses would be input in the form of responses of the system to a unit impulse. It has become apparent that many users would like the option to employ a response function based on standard RLC circuits. In addition, a wider selection of amplifier response functions should be incorporated into the ODS code data base providing the user greater flexibility in simulating an electro-optical sensor.

5.9 Alternate Techniques for Treating Transfer Functions

The problem discussed in Section 4.5 concerning troublesome transfer functions could be significantly relieved if alternate techniques for treating transfer functions were available to the user. The current version of the ODS code employs an impulse invariant technique for handling the transfer functions. This technique was selected after discussion with potential users since it preservs frequency and phase information. The use of many digital signal processing techniques requires that the phase information be retained.

The bilinear transformation technique for treating transfer functions would enable the user to employ transfer functions with poles which are much further apart than does the impulse invariant techniques. The major difficulty with the bilinear transformation technique is that it does not retain all of the phase information. For those applications in which phase information is not important the bilinear transformation technique would be quite useful. The inclusion of this technique in the ODS code would require a major rewrite of a number of routines.

6. REFERENCES

1. Brickle, F. J., Kuhlman, J. V., Cundiff, M. P., Fishburne, E. S., "Optical Detection System Model: Program Users Manual", Scientific Technology Associates, Inc., Princeton, New Jersey, SciTec Report TR-81-006, May 1981.

2. Kuhlman, J. V., Cundiff, M. P., Brickle, F. J., Fishburne, E. S., "Optical Detection System Model: Program Maintenance Manual, Vols. 1 and 2", Scientific Technology Associates, Inc., Princeton, New Jersey, SciTec Report TR-81-007.

3. Driscoll, W. G., and Vaughan, W., Handbook of Optics, McGraw-Hill Book Company, New York (1978).

4. Lissberger, P. H., J. Optical Society of America, Vol. 49, p. 121 (1959).

5. Pidgeon, C. R. and Smith, S. D., J. Optical Society of America, Vol. 54, p. 1459 (1964).

6. Hemmingway, D. J. and Lissberger, P. H., Applied Optics, Vol. 6, p. 471 (1967).

7. Wylie, C. R., Advanced Engineering Mathematics, McGraw-Hill Book Company, Inc., New York (1951).

7. APPENDIX

TEST CASE 3

Program Users Manual

```
@ODSRUN
>;
>; >> WARNING: IT IS NECESSARY TO CLEAR ALL ACTIVE ODS FILES.
>;
>* OK TO CLEAR FILES AUTOMATICALLY? [Y/N]:Y
>PIP ODSXQU.CMD;*/DE
>PIP ODSMVC.SAV/PU
>PIP *.SAV/NV=*.OLD;*/RE
>PIP *.PRM/NV=*.NUM;*/RE
>PIP ODSPIC.SAV/NV=ODSPIC.*;*/RE
PIP -- NO SUCH FILE(S)
DR0:[350,7]ODSPIC.*;*
>PIP ODSPAS.NUM=NL:
>;
>;
>RUN ODSXQT


[[[ OPTICAL DETECTION SYSTEM, V 2.0 ]]]

SCIENTIFIC TECHNOLOGY ASSOCIATES (1981)


>INPUT, EDIT, RUN? INPUT

>SELECT NEW SEQUENCE? [Y/N]: Y

                        +++ ODS MODULES +++

                            SOURCE
                            ATMOS
                            OPTICS
                            MODULATOR
                            DETECTOR
                            PREAMP
                            AMPLIFIER
                            PLOT


>ENTER MODULE LIST (TYPE '/END' TO EXIT)
>SOURCE,OPTICS,MODULATOR,PLOT,PREAMP,PLOT,/END

>HOW MANY SOURCE WAVELENGTHS (LE 32767)? 1
```

```
...THE MODULES YOU HAVE REQUESTED ARE:

                              SOURCE
                              OPTICS
                              MODULATOR     (P)
                              PREAMP        (P)


>OK? ENTER Y OR N: Y
 SAVE THIS SEQUENCE?
  WARNING: THIS WILL SUPERSEDE ANY EXISTING SEQUENCE
 [Y/N]: Y
 RUN WVINP
THIS IS THE WAVE FORM SECTION. DO YOU WANT HELP? (Y/N):
N
ENTER WAVELENGTH (IN MICRONS) FOR WHICH SIGNAL IS TO BE DETECTED:
2.5
ENTER NAME OF SIGNAL YOU WISH TO USE:
SINE
BEFORE SELECTING THE TIME STEP TO BE USED, PLEASE
CONSIDER THE FOLLOWING:

AMPLIFIER   !  ALLOWED TIME STEP (DT)
-------------------------------------


     W      !   DT <= 1.25E-04 SEC.
     H      !   DT <= 5.00E-03 SEC.
     F      !   DT <= 2.50E-04 SEC.
     C      !   DT <= 5.00E-04 SEC.
     D      !   DT <= 1.00E-03 SEC.
     G      !   DT <= 1.00E-02 SEC.



NOW PLEASE ENTER THE TIME STEP (SEC.):
0.0005
NOW PLEASE ENTER THE UPPER LIMIT ON TIME DURATION OF
THE SIGNAL (SEC.):
0.5
THIS IS THE SINE WAVE MODULE. PLEASE ENTER VALUES FOR THE FOLLOWING:
FREQUENCY
50.
AMPLITUDE
1.
THE LENGTH OF TIME BEFORE THE SINE BEGINS (DEADZONE)
0.
BASELINE
0.
```

```
DO YOU WANT TO ADD NOISE TO THIS WAVE (Y/N)?
N
>RUN LNSINP
THIS IS THE OPTICAL MATERIAL SECTION.  DO YOU WANT  HELP (Y/N)?
N
THESE ARE THE AVAILABLE FILTER TYPES:

 CORNING    VYCOR      SILICA     MGF2       SRF2       VYC7905
 INFRASIL   SAPPHIRE   MGO        TIO2       CDSE       CDS
 CDTE       SE         ZNSE       CAF2       DIAMOND    SILICON
 ZNS        GAAS       GE         LIF        NACL
   ETALON
YOU ARE NOW READY TO INPUT THE NAME OF THE OPTICAL
MATERIAL OF YOUR CHOICE (A8):
SAPPHIRE
ENTER DESIRED MATERIAL THICKNESS (IN MM)
(Type 0.0 to default to stored thickness) (E10,0):0.
>RUN MODINP

***** THIS IS THE MODULATOR INPUT SECTION *****
CHOOSE ONE OF THE FOLLOWING:
1) CHOPPER
2) CVF
3) FTS
4) CHOPPER AND CVF
5) HELP WITH CHOPPER
6) HELP WITH CVF
7) HELP WITH FTS
ENTER NUMBER OF SELECTION:1

*** FOR THE CHOPPER:
PLEASE ENTER THE FREQUENCY OF ROTATION(HERTZ): 500.
>RUN HVPINP
THIS IS THE PRE-AMP SECTION, USING THE
 HEAVISIDE OPERATORS.  DO YOU WANT HELP (Y/N)?
N
DO YOU WISH TO USE ONE OF THE SUPPLIED ROUTINES
(Y/N)?
Y
WHICH RESPONSE FUNCTION DO YOU WANT? THESE ARE THE AVAILABLE CHOICES:
         W
         H
         F
         C
         D
         G
         LP
         BP
         HP
         BR
```

```
NOW ENTER YOUR CHOICE:
D
PLEASE ENTER THE UPPER LIMIT ON THE TIME FOR THE
IMPULSE RESPONSE (E10.0).  THIS WILL BE IN SECONDS.
SELECT YOUR TIME LIMIT TO BE BETWEEN THE FOLLOWING TWO
TIMES: 2.360E-01 SECONDS AND 2.000E-02 SECONDS.
0.04
>;
>* CONTINUE WITH ODS? [Y/N]:Y
>;
>RUN ODSXQT


[[[ OPTICAL DETECTION SYSTEM, V 2.0 ]]]

SCIENTIFIC TECHNOLOGY ASSOCIATES (1981)


>INPUT, EDIT, RUN? RUN

>SELECT NEW SEQUENCE? [Y/N]: N
>PIP ODSSUM.OLD/NV=NL:
>PIP ODSSUM.NEW/NV=NL:
>PIP ODSINP.OLD/NV=NL:
>PIP ODSINP.NEW/NV=NL:
>RUN ODSWV
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>PIP ODSWV.NUM/NV=ODSWV.NUM;-1/RE
>RUN ODSLNS
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>RUN ODSMOD
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>RUN ODSGRF
>RUN ODSTOT
>PIP ODSSUM.OLD/NV=ODSSUM.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSSUM.OLD;0/RE
>RUN ODSHVP
>PIP ODSIR.NEW=ODSOUT.NEW;0/RE
>RUN CNVL
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSIR.OLD/NV=ODSIR.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>RUN ODSGRF
>RUN ODSDSP
>;
```

```
>* CONTINUE WITH ODS? [Y/N]:N
>;
>; >>
>; >> END OF ODS RUN
>; >>
>; >> (YOU MAY WISH TO PURGE FILES *.SAV AND *.PRM AT THIS POINT)
>; >>
>;
>@ <EOF>
>
```

TEST CASE 4

Program Users Manual

```
@ODSFUN
 ;
 ; >> WARNING: IT IS NECESSARY TO CLEAR ALL ACTIVE ODS FILES.
>;
>* OK TO CLEAR FILES AUTOMATICALLY? [Y/N]:Y
>PIP ODSXQU.CMD;*/DE
>PIP ODSMVC.SAV/PU
>PIP *.SAV/NV=*.OLD;*/RE
>PIP *.FRM/NV=*.NUM;*/RE
>PIP ODSPIC.SAV/NV=ODSPIC.*;*/RE
>PIP ODSPAS.NUM=NL:
>;
>;
>RUN ODSXQT


[[[ OPTICAL DETECTION SYSTEM, V 2.0 ]]]

SCIENTIFIC TECHNOLOGY ASSOCIATES (1981)


>INPUT, EDIT, RUN? INPUT

>SELECT NEW SEQUENCE? [Y/N]: Y


                    +++ ODS MODULES +++


                        SOURCE
                        ATMOS
                        OPTICS
                        MODULATOR
                        DETECTOR
                        PREAMP
                        AMPLIFIER
                        PLOT


>ENTER MODULE LIST (TYPE '/END' TO EXIT)
>SOURCE,MODULATOR,PLOT,AMPLIFIER,PLOT,/END

>HOW MANY SOURCE WAVELENGTHS (LE 32767)? 3


...THE MODULES YOU HAVE REQUESTED ARE:

                     SOURCE
                     MODULATOR       (P)
                     AMPLIFIER       (P)
>OK? ENTER Y OR N: Y
```

```
>SAVE THIS SEQUENCE?
>> WARNING: THIS WILL SUPERSEDE ANY EXISTING SEQUENCE ..
>[Y/N]: Y
>RUN WVINP
THIS IS THE WAVE FORM SECTION. DO YOU WANT HELP? (Y/N):
N
ENTER WAVELENGTH (IN MICRONS) FOR WHICH SIGNAL IS TO BE DETECTED:
4.
ENTER NAME OF SIGNAL YOU WISH TO USE:
STEP+
BEFORE SELECTING THE TIME STEP TO BE USED, PLEASE
CONSIDER THE FOLLOWING:

AMPLIFIER   !  ALLOWED TIME STEP (DT)
-----------------------------------

     W      !   DT <= 1.25E-04 SEC.
     H      !   DT <= 5.00E-03 SEC.
     F      !   DT <= 2.50E-04 SEC.
     C      !   DT <= 5.00E-04 SEC.
     D      !   DT <= 1.00E-03 SEC.
     G      !   DT <= 1.00E-02 SEC.



NOW PLEASE ENTER THE TIME STEP (SEC.):
1.E-4
NOW PLEASE ENTER THE UPPER LIMIT ON TIME DURATION OF
THE SIGNAL (SEC.):
0.1
THIS IS THE STEP-PLUS ROUTINE (A STEP UP).
PLEASE ENTER THE FOLLOWING VALUES:
 THE AMPLITUDE
1.0
LENGTH OF TIME BEFORE THE SIGNAL BEGINS (DEADZONE)
0.
THE BASELINE  (MINIMUM AMPLITUDE)
0.
DO YOU WANT TO ADD NOISE TO THIS WAVE(Y/N)?
N
>RUN WVINP
THIS IS THE WAVE FORM SECTION. DO YOU WANT HELP? (Y/N):
N
ENTER WAVELENGTH (IN MICRONS) FOR WHICH SIGNAL IS TO BE DETECTED:
4.2
ENTER NAME OF SIGNAL YOU WISH TO USE:
STEP+
NOW PLEASE ENTER THE UPPER LIMIT ON TIME DURATION OF
THE SIGNAL (SEC.):
0.09
```

```
THIS IS THE STEP-PLUS ROUTINE (A STEP UP).
PLEASE ENTER THE FOLLOWING VALUES:
 THE AMPLITUDE
2.

LENGTH OF TIME BEFORE THE SIGNAL BEGINS (DEADZONE)
0.01
THE BASELINE  (MINIMUM AMPLITUDE)
0.
DO YOU WANT TO ADD NOISE TO THIS WAVE(Y/N)?
N
>RUN WVINP
THIS IS THE WAVE FORM SECTION. DO YOU WANT HELP? (Y/N):
N
ENTER WAVELENGTH (IN MICRONS) FOR WHICH SIGNAL IS TO BE DETECTED:
4.4
ENTER NAME OF SIGNAL YOU WISH TO USE:
STEP+
NOW PLEASE ENTER THE UPPER LIMIT ON TIME DURATION OF
THE SIGNAL (SEC.):
0.08
THIS IS THE STEP-PLUS ROUTINE (A STEP UP).
PLEASE ENTER THE FOLLOWING VALUES:
 THE AMPLITUDE
0.5
LENGTH OF TIME BEFORE THE SIGNAL BEGINS (DEADZONE)

0.02
THE BASELINE  (MINIMUM AMPLITUDE)
0.
DO YOU WANT TO ADD NOISE TO THIS WAVE(Y/N)?
N
>RUN MODINP

***** THIS IS THE MODULATOR INPUT SECTION *****
CHOOSE ONE OF THE FOLLOWING:
1) CHOPPER
2) CVF
3) FTS
4) CHOPPER AND CVF
5) HELP WITH CHOPPER
6) HELP WITH CVF
7) HELP WITH FTS
ENTER NUMBER OF SELECTION:2

*** FOR THE CVF:
PLEASE ENTER THE SCAN PERIOD (IN SECONDS): 0.01
ENTER THE SPECTRAL RESOLUTION IN % OF WAVELENGTH: 2.0
PLEASE ENTER THE LOW WAVELENGTH: 3.5
PLEASE ENTER THE HIGH WAVELENGTH: 5.0
```

```
>RUN HVYINP
THIS IS THE AMPLIFIER SECTION, USING THE
 HEAVISIDE OPERATORS.  DO YOU WANT HELP (Y/N)?
N
DO YOU WISH TO USE ONE OF THE SUPPLIED ROUTINES
(Y/N)?
Y

WHICH RESPONSE FUNCTION DO YOU WANT? THESE ARE THE AVAILABLE CHOICES:
          W
          H
          F
          C
          D
          G
          LP
          BP
          HP
          BR
NOW ENTER YOUR CHOICE:
C
PLEASE ENTER THE UPPER LIMIT ON THE TIME (IN SECONDS)
FOR THE IMPULSE RESPONSE (E10.0)
SELECT YOUR TIME LIMIT TO BE BETWEEN THE FOLLOWING TWO
TIMES: 5.120E-02 SECONDS AND 2.000E-02 SECONDS.
4.E-2
>;
>* CONTINUE WITH ODS? [Y/N]:Y
>;
>RUN ODSXQT


[[[ OPTICAL DETECTION SYSTEM, V 2.0 ]]]

SCIENTIFIC TECHNOLOGY ASSOCIATES (1981)


>INPUT, EDIT, RUN? RUN

>SELECT NEW SEQUENCE? [Y/N]: N
>PIP ODSSUM.OLD/NV=NL:
>PIP ODSSUM.NEW/NV=NL:
>PIP ODSINP.OLD/NV=NL:
>PIP ODSINP.NEW/NV=NL:
>RUN ODSWV
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>PIP ODSWV.NUM/NV=ODSWV.NUM;-1/RE
>RUN ODSMOD
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
```

```
>RUN ODSGRF
>RUN ODSTOT
>PIP ODSSUM.OLD/NV=ODSSUM.NEW;0/RE
>RUN ODSWV
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>PIP ODSWV.NUM/NV=ODSWV.NUM;-1/RE
>RUN ODSMOD
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>RUN ODSGRF
>RUN ODSTOT
>PIP ODSSUM.OLD/NV=ODSSUM.NEW;0/RE
>RUN ODSWV
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>PIP ODSWV.NUM/NV=ODSWV.NUM;-1/RE
>RUN ODSMOD
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>RUN ODSGRF
>RUN ODSTOT
>PIP ODSSUM.OLD/NV=ODSSUM.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSSUM.OLD;0/RE
>RUN ODSHVY
>PIP ODSIR.NEW=ODSOUT.NEW;0/RE
>RUN CNVL
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSIR.OLD/NV=ODSIR.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>RUN ODSGRF
>RUN ODSDSP
>;
>* CONTINUE WITH ODS? [Y/N]:N
>;
>; >>
>; >> END OF ODS RUN
>; >>
>; >> (YOU MAY WISH TO PURGE FILES *.SAV AND *.PRM AT THIS POINT)
>; >>
>;
>@ <EOF>
>
>PIP *.SAV;*/DE
>PIP *.PRM;*/DE
>
```

TEST CASE 5

Program Users Manual

```
 @ODSRUN
>;
>; >> WARNING: IT IS NECESSARY TO CLEAR ALL ACTIVE ODS FILES.
>;
>* OK TO CLEAR FILES AUTOMATICALLY? [Y/N]:Y
>PIP ODSXQU.CMD;*/DE
>PIP ODSMVC.SAV/PU
PIP -- NO SUCH FILE(S)
SY0:[350,7]ODSMVC.SAV
>PIP *.SAV/NV=*.OLD;*/RE
>PIP *.PRM/NV=*.NUM;*/RE
>PIP ODSPIC.SAV/NV=ODSPIC.*;*/RE
PIP -- NO SUCH FILE(S)
DR0:[350,7]ODSPIC.*;*
>PIP ODSPAS.NUM=NL:
>;
>;
>RUN ODSXQT


[[[ OPTICAL DETECTION SYSTEM, V 2.0 ]]]

SCIENTIFIC TECHNOLOGY ASSOCIATES (1981)


>INPUT, EDIT, RUN? INPUT

>SELECT NEW SEQUENCE? [Y/N]: Y

                         +++ ODS MODULES +++


                              SOURCE
                              ATMOS
                              OPTICS
                              MODULATOR
                              DETECTOR
                              PREAMP
                              AMPLIFIER
                              PLOT


>ENTER MODULE LIST (TYPE '/END' TO EXIT)
>SOURCE,MODULATOR,PLOT,DETECTOR,PLOT,AMPLIFIER,PLOT,/END

>HOW MANY SOURCE WAVELENGTHS (LE 32767)? 3
```

```
...THE MODULES YOU HAVE REQUESTED ARE:

                         SOURCE
                         MODULATOR      (P)
                         DETECTOR       (P)
                         AMPLIFIER      (P)


>OK? ENTER Y OR N: Y
>SAVE THIS SEQUENCE?
>> WARNING: THIS WILL SUPERSEDE ANY EXISTING SEQUENCE <<
>[Y/N]: Y
>RUN WVINP
THIS IS THE WAVE FORM SECTION. DO YOU WANT HELP? (Y/N):
N
ENTER WAVELENGTH (IN MICRONS) FOR WHICH SIGNAL IS TO BE DETECTED:
4.0
ENTER NAME OF SIGNAL YOU WISH TO USE:
STEP+
BEFORE SELECTING THE TIME STEP TO BE USED, PLEASE
CONSIDER THE FOLLOWING:

AMPLIFIER   !  ALLOWED TIME STEP (DT)
-----------------------------------

     W      !   DT <= 1.25E-04 SEC.
     H      !   DT <= 5.00E-03 SEC.
     F      !   DT <= 2.50E-04 SEC.
     C      !   DT <= 5.00E-04 SEC.
     D      !   DT <= 1.00E-03 SEC.
     G      !   DT <= 1.00E-02 SEC.


NOW PLEASE ENTER THE TIME STEP (SEC.):
0.001
NOW PLEASE ENTER THE UPPER LIMIT ON TIME DURATION OF
THE SIGNAL (SEC.):
1.0
THIS IS THE STEP-PLUS ROUTINE (A STEP UP).
PLEASE ENTER THE FOLLOWING VALUES:
 THE AMPLITUDE
1.0
LENGTH OF TIME BEFORE THE SIGNAL BEGINS (DEADZONE)
0.
THE BASELINE  (MINIMUM AMPLITUDE)
0.
DO YOU WANT TO ADD NOISE TO THIS WAVE(Y/N)?
N
```

```
>RUN WVINP
THIS IS THE WAVE FORM SECTION. DO YOU WANT HELP? (Y/N):
N
ENTER WAVELENGTH (IN MICRONS) FOR WHICH SIGNAL IS TO BE DETECTED:
4.2
ENTER NAME OF SIGNAL YOU WISH TO USE:
STEP+
NOW PLEASE ENTER THE UPPER LIMIT ON TIME DURATION OF
THE SIGNAL (SEC.):
1.0
THIS IS THE STEP-PLUS ROUTINE (A STEP UP).
PLEASE ENTER THE FOLLOWING VALUES:
 THE AMPLITUDE
2.0
LENGTH OF TIME BEFORE THE SIGNAL BEGINS (DEADZONE)
0.
THE BASELINE  (MINIMUM AMPLITUDE)
0.
DO YOU WANT TO ADD NOISE TO THIS WAVE(Y/N)?
N

>RUN WVINP
THIS IS THE WAVE FORM SECTION. DO YOU WANT HELP? (Y/N):
N
ENTER WAVELENGTH (IN MICRONS) FOR WHICH SIGNAL IS TO BE DETECTED:
4.4
ENTER NAME OF SIGNAL YOU WISH TO USE:
STEP+
NOW PLEASE ENTER THE UPPER LIMIT ON TIME DURATION OF
THE SIGNAL (SEC.):
1.0
THIS IS THE STEP-PLUS ROUTINE (A STEP UP).
PLEASE ENTER THE FOLLOWING VALUES:
 THE AMPLITUDE
0.5
LENGTH OF TIME BEFORE THE SIGNAL BEGINS (DEADZONE)
0.
THE BASELINE  (MINIMUM AMPLITUDE)
0.
DO YOU WANT TO ADD NOISE TO THIS WAVE(Y/N)?
N
>RUN MODINP
***** THIS IS THE MODULATOR INPUT SECTION *****
CHOOSE ONE OF THE FOLLOWING:
1) CHOPPER
2) CVF
3) FTS
4) CHOPPER AND CVF
5) HELP WITH CHOPPER
6) HELP WITH CVF
7) HELP WITH FTS
ENTER NUMBER OF SELECTION:3
```

```
*** FOR THE FTS:
PLEASE ENTER THE LOW WAVELENGTH: 3.9
>RUN DETINP
THIS IS THE DETECTOR MODULE. YOU WILL BE ASKED TO
PICK A DETECTOR TYPE AND OPERATING TEMPERATURE
COMPATABLE WITH THE WAVELENGTH YOU HAVE ALREADY
CHOSEN.  FAILURE TO DO SO MAY BE CORRECTED DURING
THIS INPUT SESSION OR BY INVOKING THE EDIT MODE
AFTER YOU HAVE EXITTED FROM THIS ROUTINE.
DO YOU WANT HELP? (Y/N)
N
THESE ARE YOUR DETECTOR CHOICES:

         PBS
         PBSE
         SI
         INSB
         HGCDTE
PLEASE ENTER ONE OF THE ABOVE DETECTOR MNEMONICS:
INSB
THESE ARE THE AVAILABLE TEMPERATURES FOR YOUR DETECTOR
CHOICE:
              77.000
PLEASE ENTER A TEMPERATURE (IN DEGREES KELVIN):
77.
>RUN HVYIP
THIS IS THE AMPLIFIER SECTION, USING THE
 HEAVISIDE OPERATORS.  DO YOU WANT HELP (Y/N)?
N
DO YOU WISH TO USE ONE OF THE SUPPLIED ROUTINES
(Y/N)?
Y
WHICH RESPONSE FUNCTION DO YOU WANT? THESE ARE THE AVAILABLE CHOICES:
         W
         H
         F
         C
         D
         G
         LP
         BP
         HP
         BR
NOW ENTER YOUR CHOICE:
HP

IT WILL NOT BE NECESSARY TO ENTER A MAXIMUM TIME.
IT WILL BE COMPUTED BASED ON A FIXED NUMBER OF POINTS = 256.
```

```
NOW YOU MAY ENTER THE FIRST FREQUENCY.
PLEASE REMEMBER THAT IF YOU HAVE CHOSEN LP OR HP AMPLIFIERS,
THAT THIS IS THE CUTOFF FREQUENCY.  IF YOU HAVE CHOSEN THE
BP OR BR AMPLIFIERS, THEN THIS IS THE FREQUENCY OF THE
LEADING EDGE OF THE BAND. PLEASE ENTER THE 1ST FREQUENCY:
100.
NOW YOU MAY ENTER THE 2ND FREQUENCY.
PLEASE REMEMBER THAT IF YOU HAVE CHOSEN LP OR HP AMPLIFIERS,
THAT THIS FREQUENCY WITH THE 1ST FREQUENCY MARK THE
TRANSITION BAND.  FOR THE LP, THIS WILL BE > 1ST FREQ.
FOR THE HP, THIS WILL BE < 1ST FREQ.  IF YOU HAVE CHOSEN
THE BP OR BR AMPLIFIERS, THEN THIS IS THE FREQUENCY OF
THE TRAILING EDGE OF THE BAND. PLEASE ENTER THE 2ND FREQUENCY:
50.
PLEASE ENTER THE ATTENUATION (IN DB):
20.
>;
>* CONTINUE WITH ODS? [Y/N]:Y
>;
>RUN ODSXQT


[[[ OPTICAL DETECTION SYSTEM, V 2.0 ]]]

SCIENTIFIC TECHNOLOGY ASSOCIATES (1981)


>INPUT, EDIT, RUN? RUN

>SELECT NEW SEQUENCE? [Y/N]: N
>PIP ODSSUM.OLD/NV=NL:
>PIP ODSSUM.NEW/NV=NL:
>PIP ODSINP.OLD/NV=NL:
>PIP ODSINP.NEW/NV=NL:
>RUN ODSWV
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>PIP ODSWV.NUM/NV=ODSWV.NUM;-1/RE
>RUN ODSMOD
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>RUN ODSGRF
>RUN ODSDET
>PIP ODSIR.NEW=ODSOUT.NEW;0/RE
>RUN CNVL
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSIR.OLD/NV=ODSIR.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
```

```
>RUN ODSGRF
>RUN ODSTOT
>PIP ODSSUM.OLD/NV=ODSSUM.NEW;0/RE
>RUN ODSWV
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>PIP ODSWV.NUM/NV=ODSWV.NUM;-1/RE
>RUN ODSMOD
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>RUN ODSGRF
>RUN ODSDET
>PIP ODSIR.NEW=ODSOUT.NEW;0/RE
>RUN CNVL
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSIR.OLD/NV=ODSIR.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>RUN ODSGRF
>RUN ODSTOT
>PIP ODSSUM.OLD/NV=ODSSUM.NEW;0/RE
>RUN ODSWV
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>PIP ODSWV.NUM/NV=ODSWV.NUM;-1/RE
>RUN ODSMOD
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>RUN ODSGRF
>RUN ODSDET
>PIP ODSIR.NEW=ODSOUT.NEW;0/RE
>RUN CNVL
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSIR.OLD/NV=ODSIR.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>RUN ODSGRF
>RUN ODSTOT
>PIP ODSSUM.OLD/NV=ODSSUM.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSSUM.OLD;0/RE
>RUN ODSHVY
>PIP ODSIR.NEW=ODSOUT.NEW;0/RE
>RUN CNVL
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSIR.OLD/NV=ODSIR.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
```

```
 RUN ODSGRF
 RUN ODSDSP
>;
>* CONTINUE WITH ODS? [Y/N]:N
>;
>; >>
>; >> END OF ODS RUN
>; >>
>; >> (YOU MAY WISH TO PURGE FILES *.SAV AND *.PRM AT THIS POINT)
>; >>
>;
>@ <EOF>
>
```

TEST CASE 6

Program Users Manual

```
@ODSRUN
>;
>; >> WARNING: IT IS NECESSARY TO CLEAR ALL ACTIVE ODS FILES.
>;
>* OK TO CLEAR FILES AUTOMATICALLY? [Y/N]:N
>* DO YOU WISH TO EXIT? [Y/N]:N
>;
>RUN ODSXQT


[[[ OPTICAL DETECTION SYSTEM, V 2.0 ]]]

SCIENTIFIC TECHNOLOGY ASSOCIATES (1981)


>INPUT, EDIT, RUN? INPUT

>SELECT NEW SEQUENCE? [Y/N]: Y

                        +++ ODS MODULES +++

                             SOURCE
                             ATMOS
                             OPTICS
                             MODULATOR
                             DETECTOR
                             PREAMP
                             AMPLIFIER
                             PLOT


>ENTER MODULE LIST (TYPE '/END' TO EXIT)
>SOURCE,PLOT,PREAMP,PLOT,AMPLIFIER,PLOT,/END

>HOW MANY SOURCE WAVELENGTHS (LE 32767)? 1


...THE MODULES YOU HAVE REQUESTED ARE:

                     SOURCE        (P)
                     PREAMP        (P)
                     AMPLIFIER     (P)


>OK? ENTER Y OR N: Y
```

```
>SAVE THIS SEQUENCE?
>> WARNING: THIS WILL SUPERSEDE ANY EXISTING SEQUENCE <<
>[Y/N]: Y
>RUN WVINP
THIS IS THE WAVE FORM SECTION. DO YOU WANT HELP? (Y/N):
N
ENTER WAVELENGTH (IN MICRONS) FOR WHICH SIGNAL IS TO BE DETECTED:
4.
ENTER NAME OF SIGNAL YOU WISH TO USE:
SQUARE
BEFORE SELECTING THE TIME STEP TO BE USED, PLEASE
CONSIDER THE FOLLOWING:

AMPLIFIER   !  ALLOWED TIME STEP (DT)
-------------------------------------


     W      !   DT <= 1.25E-04 SEC.
     H      !   DT <= 5.00E-03 SEC.
     F      !   DT <= 2.50E-04 SEC.
     C      !   DT <= 5.00E-04 SEC.
     D      !   DT <= 1.00E-03 SEC.
     G      !   DT <= 1.00E-02 SEC.



NOW PLEASE ENTER THE TIME STEP (SEC.):
0.0005
NOW PLEASE ENTER THE UPPER LIMIT ON TIME DURATION OF
THE SIGNAL (SEC.):
0.5
THIS IS THE SQUARE WAVE.  PLEASE ENTER THE FOLLOWING VALUES:
THE AMPLITUDE
1.0
THE WIDTH OF THE BASE OF THE SQUARE WAVE
0.1
THE SEPARATION BETWEEN SQUARE WAVE PULSES
0.1
THE LENGTH OF TIME BEFORE THE SQUARE WAVE BEGINS(DEADZONE)
0.05
THE BASELINE  (AMPLITUDE MINIMUM)
0.
DO YOU WANT TO ADD NOISE TO THIS WAVE (Y/N)?
Y
DO YOU WANT [WHITE] NOISE OR [1/F] NOISE ?
WHITE
YOU WANT NOISE TO BE ADDED TO YOUR CHOSEN INPUT SIGNAL.
PLEASE ENTER AN RMS AMPLITUDE.
0.4
```

```
>RUN HVPINP
THIS IS THE PRE-AMP SECTION, USING THE
 HEAVISIDE OPERATORS.  DO YOU WANT HELP (Y/N)?
N
DO YOU WISH TO USE ONE OF THE SUPPLIED ROUTINES
(Y/N)?
N
DO YOU WANT TO INPUT POLES AND ZEROES DIRECTLY (Y/N)?
Y
IS THERE A QUADRATIC TERM PRESENT (Y/N)?
N
PLEASE ENTER THE NUMBER OF POLES:
1
PLEASE ENTER THE NUMBER OF ZEROES:
0
PLEASE ENTER POLE #1:
490.2
PLEASE ENTER THE VALUE OF A PREFACTOR :
1.
PLEASE ENTER THE UPPER LIMIT ON THE TIME FOR THE
IMPULSE RESPONSE (E10.0).  THIS WILL BE IN SECONDS.
SELECT YOUR TIME LIMIT TO BE BETWEEN THE FOLLOWING TWO
TIMES: 2.560E-01 SECONDS AND 0.000E-01 SECONDS.
0.02
>RUN HVYINP
THIS IS THE AMPLIFIER SECTION, USING THE
 HEAVISIDE OPERATORS.  DO YOU WANT HELP (Y/N)?
N
DO YOU WISH TO USE ONE OF THE SUPPLIED ROUTINES
(Y/N)?
Y
WHICH RESPONSE FUNCTION DO YOU WANT? THESE ARE THE AVAILABLE CHOICCS:
         W
         H
         F
         C
         D
         G
         LP
         BP
         HP
         BR
NOW ENTER YOUR CHOICE:
LP

IT WILL NOT BE NECESSARY TO ENTER A MAXIMUM TIME.
IT WILL BE COMPUTED BASED ON A FIXED NUMBER OF POINTS = 256.
```

```
NOW YOU MAY ENTER THE FIRST FREQUENCY.
PLEASE REMEMBER THAT IF YOU HAVE CHOSEN LP OR HP AMPLIFIERS,
THAT THIS IS THE CUTOFF FREQUENCY.  IF YOU HAVE CHOSEN THE
BP OR BR AMPLIFIERS, THEN THIS IS THE FREQUENCY OF THE
LEADING EDGE OF THE BAND. PLEASE ENTER THE 1ST FREQUENCY:
100.
NOW YOU MAY ENTER THE 2ND FREQUENCY.
PLEASE REMEMBER THAT IF YOU HAVE CHOSEN LP OR HP AMPLIFIERS,
THAT THIS FREQUENCY WITH THE 1ST FREQUENCY MARK THE
TRANSITION BAND.  FOR THE LP, THIS WILL BE > 1ST FREQ.
FOR THE HP, THIS WILL BE < 1ST FREQ.  IF YOU HAVE CHOSEN
THE BP OR BR AMPLIFIERS, THEN THIS IS THE FREQUENCY OF
THE TRAILING EDGE OF THE BAND. PLEASE ENTER THE 2ND FREQUENCY:
120.
PLEASE ENTER THE ATTENUATION (IN DB):
30.
>;
>* CONTINUE WITH ODS? [Y/N]:Y
>;
>RUN ODSXQT


[[[ OPTICAL DETECTION SYSTEM, V 2.0 ]]]

SCIENTIFIC TECHNOLOGY ASSOCIATES (1981)


>INPUT, EDIT, RUN? RUN

>SELECT NEW SEQUENCE? [Y/N]: N
>PIP ODSSUM.OLD/NV=NL:
>PIP ODSSUM.NEW/NV=NL:
>PIP ODSINP.OLD/NV=NL:
>PIP ODSINP.NEW/NV=NL:
>RUN ODSWV
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>PIP ODSWV.NUM/NV=ODSWV.NUM;-1/RE
>RUN ODSGRF
>RUN ODSTOT
>PIP ODSSUM.OLD/NV=ODSSUM.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSSUM.OLD;0/RE
>RUN ODSHVP
>PIP ODSIR.NEW=ODSOUT.NEW;0/RE
>RUN CNVL
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSIR.OLD/NV=ODSIR.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>RUN ODSGRF
```

```
>RUN ODSHVY
>PIP ODSIR.NEW=ODSOUT.NEW;0/RE
>RUN CNVL
>PIP ODSINP.OLD/NV=ODSINP.NEW;0/RE
>PIP ODSIR.OLD/NV=ODSIR.NEW;0/RE
>PIP ODSINP.NEW/NV=ODSOUT.NEW;0/RE
>RUN ODSGRF
>RUN ODSDSP
>;
>* CONTINUE WITH ODS? [Y/N]:N
>;
>; >>
>; >> END OF ODS RUN
>; >>
>; >> (YOU MAY WISH TO PURGE FILES *.SAV AND *.FRM AT THIS POINT)
>; >>
>;
>@ <EOF>
>PIP *.SAV;*/DE
>PIP *.FRM;*/DE
>
```

DATE
FILMED
7 - 8